ELECTRIC LIGHT FOR THE FARM

N. H. SCHNEIDER

ELECTRIC LIGHT

FOR

THE FARM

PART I.

LOW VOLTAGE ELECTRIC LIGHTING WITH THE STORAGE BATTERY

PART II.

WIRING HOUSES FOR THE ELECTRIC LIGHT

BY

NORMAN H. SCHNEIDER

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LOW VOLTAGE

ELECTRIC LIGHTING

WITH

THE STORAGE BATTERY

SPECIALLY APPLICABLE TO COUNTRY HOUSES, FARMS, SMALL SETTLEMENTS, LAUNCHES, YACHTS, ETC.

BY

NORMAN H. SCHNEIDER

AUTHOR OF "ELECTRICAL INSTRUMENTS AND TESTING," "MANAGEMENT OF ELECTRIC POWER PLANTS," ETC.

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PREFACE

The object of this book is to give practical information on small low voltage electric light plants suitable for farms, isolated houses, stores and country homes in general.

Many of the outfits described are suitable for use on yachts or launches where electricity is desirable for the operation of search lights or cabin lights.

Sailing vessels equipped with auxiliary engines or employing a separate engine for the electric outfit may also enjoy the advantages of electric light.

Full details are given showing how to estimate the size and number of lights required, their best location and most convenient means of control, and the plant necessary to furnish the current.

It is planned to use a storage battery to supply the electric current as such a battery may be charged at odd times to supply the current when needed, thereby obviating the need for anyone to be in attendance at the plant except during convenient hours. One of the great advantages of a storage battery lies in the fact that it will supply power for a time far greater than that of the generator which charges it. For example an electric motor of five or six horsepower or even larger might be operated for a few hours from a battery which was normally charged by means of a three-horse power engine.

The outfits of storage batteries and generators described here have been selected from those which are the most efficient and require the minimum of attention.

Practically no technical knowledge is required to operate these plants except what may be learned from this book and from the instructions furnished by the manufacturers of the apparatus.

It has been considered best to treat the practical directions for wiring houses in a separate part, as it is an important subject worthy of more space than could be given here.

The writer desires to acknowledge the assistance derived from illustrations or information kindly furnished by the Electric Storage Battery Company, of Philadelphia, Pa.; The Edison Storage Battery Company; The Alamo Manufacturing Company, Hillsdale, Mich.; The American Battery Company; Fairbanks Morse Company, of Chicago, Ill.; The Ward Leonard Electric Company, of Bronxville, N. Y.; The Schug Electric Manufacturing Company, of

Detroit, Mich.; The Western Electric Company, of New York, N. Y.; and The Ohio Electric Works, of Cleveland, Ohio.

Representative and well established manufacturers have been chosen in the selection made and all the apparatus described is of standard design and first class workmanship.

NORMAN H. SCHNEIDER.

Cleveland, O.

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CHAPTER I

INTRODUCTION

The advent of improved machinery and the adoption of scientific methods in agriculture have been the two principal factors in lightening the burden of the farmer.

To-day there are few of these tillers of the soil who feel compelled to retire to bed soon after dusk in order to get that rest for their exhausted bodies as will fit them for another day of unremitting back-breaking labor.

Rather the number is rapidly increasing of those who look forward to the evening for reading or social relaxation, and the days of the evil smelling and dangerous oil lamp on the kitchen table are long past.

The modern farmer living in a modern house has electric bells, an electric telephone and probably inter-phone communication among the departments of the farm.

It is but natural then that this question of illuminating his buildings safely and efficiently should have directed his mind towards electricity for light.

There are many well-known domestic conveniences and labor saving articles on the market such as motors for sewing machines, flat irons, vacuum cleaners, cooking stoves and heating devices which may be used economically on circuits of not less than 25 volts.

They have proven their worth to the busy housewife and form to-day as strong an argument for having electricity in the home as does that of illumination.

The safety of properly installed electric lights is so far above that of any other form of illuminant, that the very freedom from fire danger alone would commend it.

With few exceptions farms are rarely near enough to an electric plant for the buying of current, and the need of a reliable and inexpensive private plant for his individual use has become more urgent each day.

To be successful the plant must be easy to operate and require only those simple repairs that the ordinary help around the farm is competent to provide.

Most modern farms of any size are provided with some sort of gas or gasoline engine used, perhaps, to pump water or for other similar duty, and an electric outfit that could be attached to one of these engines would bid fair to have a large field of employment.

Such an outfit might consist of a generator which would charge a set of batteries during the day, taking but a slight additional amount of fuel, the battery to give back at night its quota of electricity in the shape of a cheerful and satisfying illumination. A plant with its own engine would be satisfactory or where the geographical situation was suitable, a water wheel could be used to operate the generator, even a windmill can well be adapted to this service.

Then again there were many dwellings situated away from the wires of electric light companies that would welcome a plant of their own, if the installation and operation of a plant were within reason.

Heretofore the complications and the need for relatively large power to give a modicum of light have been prohibitive. The lamps needed so much power before they would give their return in light, large batteries were necessary and their cost and upkeep made them almost prohibitive.

To-day as will be pointed out, the plant may be had, complete, at reasonable cost and needing but a minimum of attention.

The Watt. Without going into a lengthy discussion on the electrical units, it becomes necessary to explain once for all a few of the rules that govern electric currents, and their application to the subject at hand.

To do any work requires the expenditure of power; to cause an electric lamp to burn, consumes power. This power is measured in watts, a watt being the power exerted by a current of one ampere flowing through the lamp at a pressure of one volt.

Briefly comparing an electric circuit with a water pipe, the ampere at a pressure of one volt might be likened to a water flow of one gallon at a pressure of one pound per square inch, and the watt to the power exerted by that gallon at one pound pressure.

Now if there was only one-half a gallon flowing it would have to be under two pounds pressure to equal the first stated power. Similarly an electric current at one ampere and one volt being one watt, a current of one-half ampere at two volts would equal the same, one watt. And likewise the power of a current of one ampere at one hundred watts being one hundred watts, would equal the power of five amperes at twenty volts, still one hundred watts.

The practical application of these remarks will be shown as the subject of the current consumption of lamps is discussed.

The Tungsten Lamp and the Battery. The advent of the tantalum lamp and the tungsten lamp has swept away perhaps the greatest obstacle to the employment of storage batteries for small domestic electric light installations.

The power consumption of the carbon lamp which averages 4 watts per candle, could be supplied in one of two ways, by the use of high voltages and consequently a large number of battery cells, or by the employment of lower voltage lamps which needed fewer, but much larger cells to deliver the current for them. No matter which means was adopted the actual power delivered to the lamps had to be the same and the first cost and also the upkeep were high.

The tungsten lamp is made to-day with an efficiency of 1¼ watts per candle, and gives a whiter light for a greater length of life than the most efficient form of carbon lamp that can be manufactured. To put an illustration into plain words, the battery that would have served a given number of carbon lamps for 8 hours with a very considerable lessening of candle power during the last three or four hours will furnish light by means of tungsten lamps for over 25 hours, and with a far more uniform brilliancy.

Moreover, on account of the peculiar action of carbon when subjected to heat, there had to be provided some means of regulation in order to maintain a fairly uniform candle power as the voltage decreased per cell.

The most usual method was by using a larger number of cells, cutting out a few of the cells at the start when they were freshly charged, but cutting them in one by one as the voltage dropped, owing to the battery becoming discharged.

Another reason for using a large number of cells and a high voltage was to keep down the area of the copper wire used, and so lessen the cost for wire which was often a considerable item.

In plants feeding a large number of lights this latter reason was of great importance as will be seen after a glance at some of the pecularities of the electric current.

The more amperes to be carried the larger must be the diameter of the wire, and vice versa. So, given one hundred watts of power to transmit, it should be clear that it would take a smaller wire and cost far less to use this one hundred watts in the shape of one ampere and one hundred volts, than it would be to have ten amperes and ten volts, which would equal the same wattage.

Therefore it has been customary to use lamps of one hundred volts or thereabouts, as this gave a small current, about one-half ampere for a sixteen candle power lamp.

Although isolated storage battery plants generally used a somewhat lower voltage than this, still the battery consisted of a large number of cells, was very costly, and a troublesome affair unless a competent attendant was hired to look after it.

With the tungsten lamp the power being cut to one-third, the amperes may also be reduced to one-third, or what will be better in the case of a small plant, the voltage reduced and thereby the number of cells of battery, as the total current will be small, at least in the plants to be described in the course of this book.

Furthermore the tungsten lamp does not vary in its candle power nearly as much as does a carbon lamp upon a change in the voltage supplied to it. The extra or "end cells" (often in the case of carbon lamps being more than fifteen per cent. of the total) may then be reduced in number or dispensed with and a simpler form of regulator used in their stead.

Summing Up. To sum up, the tungsten lamp has reduced the power needed and consequently the battery and dynamo are smaller than those required for carbon lamps. We are going a step farther in order to adapt the system to the needs of the small house and slim pocketbook, by adopting a slightly lessened candle power with a corresponding reduction all down the line.

Essentials of the Plant. The essential parts of the electric lighting outfit are, the lamps and accessories, the storage battery, the generator which charges the battery; and the engine or other source of power employed to operate the generator. To these may be added the switchboard which is a panel of slate or marble on which is mounted the apparatus which controls the generator and the battery.

The general construction of the various types of storage batteries will be first discussed, the actual operations involved in handling them being treated in a latter chapter.

CHAPTER II

THE STORAGE BATTERY

The term Primary battery has long been given to the class of galvanic cells in which the exhausted chemicals or elements are replenished by hand. The term Secondary battery, or storage battery is given to those cells which are replenished by the continued passage of an electric current through them.

There is, however, no important difference in the two classes. They have been grouped according .to the manner in which they are handled. A storage battery can be replenished by the addition of new chemicals even as most primary batteries may be restored to a great extent by the electric current.

For example, the well known Leclanche cell used for ringing small bells, may, upon exhaustion, be connected to an electric current and be duly revived enough to perform its task for a short lease of life. And the lead storage cell may have its exhausted plates replaced with new ones and be thereby restored to work. But the limits in this direction are practical rather than theoretical, and certain combinations of elements have been set aside to make the two classes, owing to their being the better suited thereby.

The principal storage batteries in use to-day are those using lead plates in dilute sulphuric acid, and the one which in a class by itself, is composed of sheet iron and nickel in a solution of caustic potash.

Batteries have been constructed with elements of lead and zinc, but for reasons too lengthy to discuss here, have gone out of general use.

Simple Storage Battery. If two plates of clean sheet lead be immersed in a solution of say five parts of water to one of sulphuric acid and left for an hour, little, if any change will appear to have taken place on the surface of the lead. But if each plate be connected by means of a copper wire to one pole of two cells of dry battery in series as one would connect a bell, substituting the two plates for the two binding posts of the bell, in a few minutes a change will be observed to take place.

The plate connected to the carbon of the dry battery will be seen to turn darker, and in a short while will have become dark brown, while the plate connected to the zinc of the dry battery will not appear to have changed.

What has happened is that the dark plate has become covered with a deposit of lead peroxide, the solution of acid having parted with some of its oxygen which has attacked the lead.

By now disconnecting the dry battery and connecting an electric bell to the lead plates, the bell will ring, probably faintly, but will at any rate indicate the presence of an electric current flowing from the lead plates.

If this discharging of the plates by means of the bell or other means is continued, after a while the plates will become exhausted. The peroxide on the one plate of lead and the plain lead of the other have formed a battery cell in the sulphuric acid, just as the carbon and the zinc form a battery in the dry cell.

And when all the peroxide has been used up, the battery is exhausted and must have more added, which is done as in the first case by sending more current back into the lead plates and forming more peroxide. This is easily proved by connecting up the dry battery and the lead plates again when, after awhile there will be sufficient strength to ring the bell.

It will be also clearly seen that the battery does not store electricity, but stores chemicals, or chemical action.

If large plates of lead are used and kept connected to large batteries for a considerable time, the current they will give back will be also large, and it is therefore easy to see that a number of these plates might be put in jars of solution and connected up to each other like dry batteries are connected. They would then give very powerful currents after having been charged from large batteries, or from the electric light mains.

In practice the plates of a storage battery are formed mechanically, that is, they are first made up in the form of skeleton frames or grids, and having a number of pockets or holes, and these pockets filled with the required prepared lead. Heavy pressure is applied to the material and it is thereby so firmly fixed into the grids that it becomes almost an integral part of them.

It is not proposed here to go into the merits of the various makes of storage batteries, but merely to give a short description of one type; as a matter of fact the manufacture has been so improved within recent years, that there are many batteries on the market of equal merit.

The rule for guidance should be to deal with a company that has a reputation for the excellence of its goods, in which case there will be some guarantee that matters will be adjusted if there is any trouble.

The Chloride Accumulator or Storage Battery. This battery is made by the Electric Storage Battery Company of Philadelphia, and a cell of the D5 size is illustrated in Fig. 1.

The Edison Storage Battery. The Edison storage battery presents the most radical departure from the beaten paths of storage battery construction practice that has been seen in years.

Heretofore experience had demonstrated that combinations other than lead—lead in an elec-

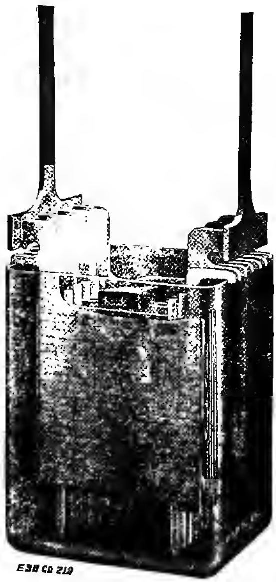

Fig. 1

trolyte of dilute sulphuric acid, were valueless outside the laboratory.

In the Edison cell, however, a combination of nickel and oxide of iron in an electrolyte of caustic potash in water, is producing results that bid fair to give this cell a large field of usefulness. The complete cell comprises a positive and a negative element, each made up of several plates of peculiar construction, installed in a retaining can holding the electrolyte and sealed by an air tight cover.

The postive plate consists of a nickel plated steel grid holding a number of nickel plated steel tubes filled with nickel hydrate and layers of electro-chemically deposited nickel flakes.

The negative plate is also a nickel plated steel grid supporting a number of perforated steel pockets, which are filled with oxide of iron.

A number of these negative and postive plates are assembled in a nickel plated steel retaining can and are insulated from each other by hard rubber separators.

The case cover of the can is welded on after installation of the elements, being provided with bushed holes for the plate terminals, filling holes for the replenishing of the water supply, and a gas valve or separator which holds back the moisture and permits the gas only to escape.

A twenty-one per cent. solution of caustic potash in water forming the electroylte, covers the plates to an average height of one-half inch.

The charging e.m.f. of the cell starts at 1.45 volts and rises to 1.85, the discharge voltage ranging from 1.45 to 1.00, the working voltage remaining fairly steady between 1.3 and 1.2 volts for the major portion of the discharge.

The complete cell is very light, having an output of 16.8 watts per pound weight.

The principal points in favor of the Edison cell over the lead-lead combinations, seem to be those of lightness, ability to withstand excessive charging and discharging without damage, and ease of maintenance.

But for the private house plant such as this book details, the question of price is important and as the cost of the Edison cell is high, and its voltage relatively low, requiring a large number of cells, it is not perhaps as well suited for our present needs as the lead-lead type.

Furthermore, its qualities of lightness, of prime importance in automobile work, are of little account here, as likewise its ability to withstand successfully heavy charges and discharges, while as for maintenance, this in a standard lead-lead battery is well within the capacity of a person of average intelligence.

Portable Batteries. In the case of summer camps or bungalows wired for electric light on this low voltage system, a portable battery might be of service if it is not desired to install a complete plant. This battery would be taken to the nearest charging station in a wagon or automobile, and charged. Or two batteries may be used so that one is always charged or charging while the other is in use. The voltage and capacity of this battery will be determined the same way as for a complete plant, that is by the number of lamps, their hours of burning and the current they consume.

Two sizes of the batteries manufactured by the Electric Storage Battery Company are given below in Table I while Table II shows portable batteries of the Ohio Electric Company.

It will be noted that they are three cell equipments, this being a convenient number to keep the weight within reason.

As the three cells will give only six volts, two sets will be needed for a twelve volt, or three for an eighteen volt system.

TABLE I

Portable batteries in hardwood cases provided with handles. Electric Storage Battery Company.

Cells	Type	Amperes	Volts	Ampere hours	Weight in lbs.
3	D5	5	6	40	62
3	D7	7½	6	60	83

TABLE II

Portable battery in oak case with handles. The Ohio Electric Company.

Cells	Amperes	Volts	Ampere hours	Weight
3	10	6	80	45
3	12	6	100	55

Series and Multiple Connection. It may be noted here that battery cells may be added together to give a higher voltage *or* a greater amperage or capacity, but the same number of cells cannot be connected to give both increased voltage and increased amperage at the same time.

When arranged to give a higher voltage the connection is called a series one, when arranged to give a greater amperage they are said to be in multiple (or parallel.)

Electric Light From Primary Batteries. Although it has been before taken for granted that the current would be supplied from a storage battery, there is an idea prevalent among a large class of people that it is possible to use primary batteries for the work.

In the first case all primary batteries need frequent renewals of their parts, involving messy and troublesome operations. Then with few exceptions (the copper oxide batteries being the exception), they waste themselves even when disconnected from the circuit.

Dry batteries are out of the question for all but very intermittent service, such as flash lights and portable lights, as their capacity is small and their voltage falls rapidly when they are made to deliver current for more than a few seconds at one time.

The best primary batteries made are those having copper oxide plates and zinc plates in a solution of caustic soda or potash. They are very valuable for bell ringing and railroad work, or for intermittent work requiring a large current for long periods at a time.

But even here, considering the Gladstone-Lalande and the Nungesser cells, both standards in their class, the renewal cost is prohibitive where practical home lighting is considered.

For example, a cell with an output of 300 to 400 ampere hours would cost over $3.00 per cell, and as the voltage is about .7 volts, at least 18 cells would be required for the 10 volt system. Taking the average burning per night as 20 ampere hours, at the above voltage, the cost would be at least $54.00 for the battery and the renewals each fifteenth night after the first fifteen nights would approach $22.50, an average of $1.50 per night.

And this with the only type of battery that can be considered, all others of higher voltage being prohibitive on account of electrical characteristics or frequent renewals.

Although greater claims may be made for some special form of primary battery, no doubt exists that there is to-day no primary battery manufactured or even designed which will give anything near the results to be obtained from the storage battery.

CHAPTER III

Estimating the Installation

The Number of Lights Needed. Having discussed the various types of storage batteries suitable for the small private plant, the next matter to be considered is actually the gist of the whole subject, namely, the number and power of the lights, and their location together with the most convenient means of controlling them.

This will naturally lead to matters pertaining to the battery and its charging apparatus, as the details of the illumination will to a very great extent decide the details of the plant.

Location of Outlets. With regard to the number of lamps or outlets, the capacity of the plant will limit the number that can be burned at one time, but almost any number may be installed if only the correct number be lighted at one time. The number of outlets will, however, be probably controlled by the expense and by a consideration of reasonable requirements.

After providing the necessary outlets, that is those in the rooms in the house, there remain the hallway, the cellar and the porches to consider.

As to the porch, that is a matter of individual need, but the cellar and hallway are places where the convenience of electric lights should not be understimated.

The cellar light should be controlled by a switch set in the wall just inside the cellar stairway, so that it may be turned on before descending the stairs.

The hall light should be controlled from two places by means of a switch in each place. This allows of the light being turned on or off from either downstairs or upstairs, and is done by using special "three way" switches. The convenience of this arrangement when one has to go downstairs at night is evident. One can light up the hall before going down and leave it burning until one has returned upstairs.

With respect to the exact location of the outlets, the center of ordinary rooms are usually taken for ceiling lights. These lights may be either drops, that is sockets hanging from a length of flexible cord, regular electroliers, or mazdaliers, a form of hanging fixture much used for tungsten lamps as they take up any shock and prevent the fragile filament breaking through heavy walking or shaking of the floor above.

In bedrooms a convenient place for the outlet is just in front of the mirror, the lamp hanging about six feet six inches from the floor, and being so placed that it lights the top of the head and face of a person standing before the mirror or dresser.

In bathrooms the fixture may be a plain ceiling receptacle or better, a mazdalier hung in front of the mirror so that when it is desired to shave in the bathroom, the light will be where it will do the most good.

Porch lights are more in the line of luxuries for small installation, but if included, should be controlled by a switch located just inside the door.

Size of the Lamp. With regard to the size of lamp desired for a typical plant, much will depend upon the amount of money to be spent. The larger the lamps or the more of them, the greater will be the cost for sufficient battery capacity.

Before considering a small plant in detail, it will be well to note the ordinary sizes of lamps and their current consumption.

Generally speaking the efficiency of the tungsten lamp is one and one-quarter watts per candle as has been stated before. Therefore, an 8 c. p. lamp would require 10 watts, and a 20 c. p. lamp 25 watts.

The latter is the largest lamp to be considered in a small, inexpensixe plant, but the 8 c. p. at 10 watts will be taken here as the standard for general use, it giving sufficient light for ordinary domestic purposes such as in the kitchen, diningroom, bedroom, or bathroom, two being used in the sitting room or where a brighter light is desired.

In estimating the candle power needed to illu-

Fig. 2

minate a given space, the color of the walls and ceiling are important. It must be remembered that dark wall papers do not reflect much light and that the same candle power in a room with dark paper, would appear far less brilliant than if in a room with white walls.

Where direct or concentrated light is required as for reading, a portable table stand can be bought for a small sum ready equipped with a shade, cord and attachment plug which may be screwed into any convenient socket. This by bringing the light nearer the object to be illuminated, lessens the actual candle power required, which is of importance.

Fixtures. Mazdaliers have been mentioned before as being special fixtures for tungsten lamps, they are made in a large variety of designs, see Figs. 2, 3 and 4, and bid fair to replace many of the older forms of fixtures. Their great advantage outside of their artistic designs is that they are easy to hang, and absorb shocks in the ceiling or walls which would jar the lamps and probably break the fragile tungsten filament. The actual life of a tungsten or mazda lamp runs up into the thousands of hours, under conditions of normal voltage, but mechanical shocks will shorten this into a few hours, or even seconds.

If burned in suitable fixtures and kept free from shock there is no reason why the lamps should not give their maximum life. They should never be taken out of the sockets and wiped, but wiped carefully while burning, as at that time the filament is at its least brittleness.

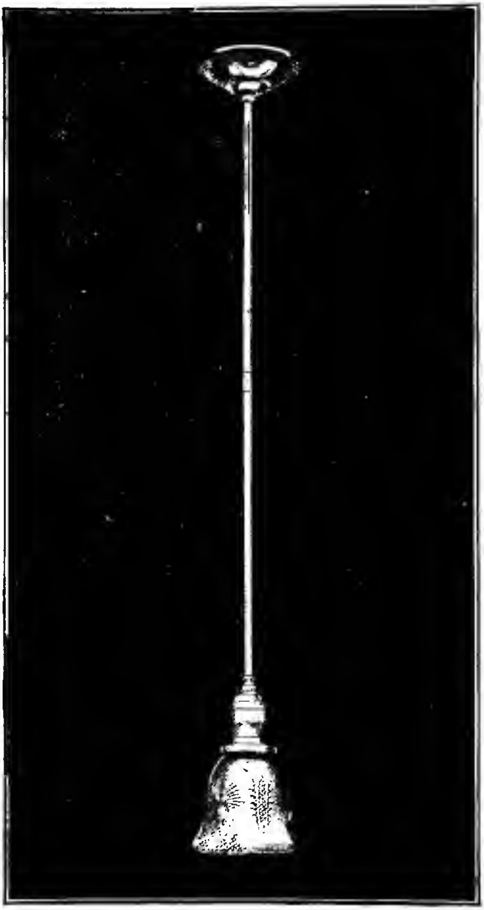

Fig. 3.

around as in examining automobiles, carbon lamps should be used as the filament is far less brittle.

Shades and Globes. Ground glass shades absorb much of the light, but by their softening and diffusing effects are to be preferred in sitting rooms or where appearance as well as illumination are of account.

Glass shades which are open at the bottom are to be preferred to closed balls or globes. The latter were much in fashion for a time, but now, except for special effects, are being replaced by open shades in all private house installations.

Switches and Finishes. Of switches there are several to choose from, the ordinary snap switch being the easiest to put up and is very efficient. Then there are switches that set flush with the wall and are operated by push buttons, but these should be set in iron boxes to protect the wires and secure the switch in position. Others with removable keys may be used where it is desired to lock the current on or off at some particular point.

For pendent lights there are small push switches hanging from a cord which is attached to the wires inside the fixture. But in a small installation, the wall type is preferable.

Switches and fixtures can be obtained in a variety of finishes to match any color scheme.

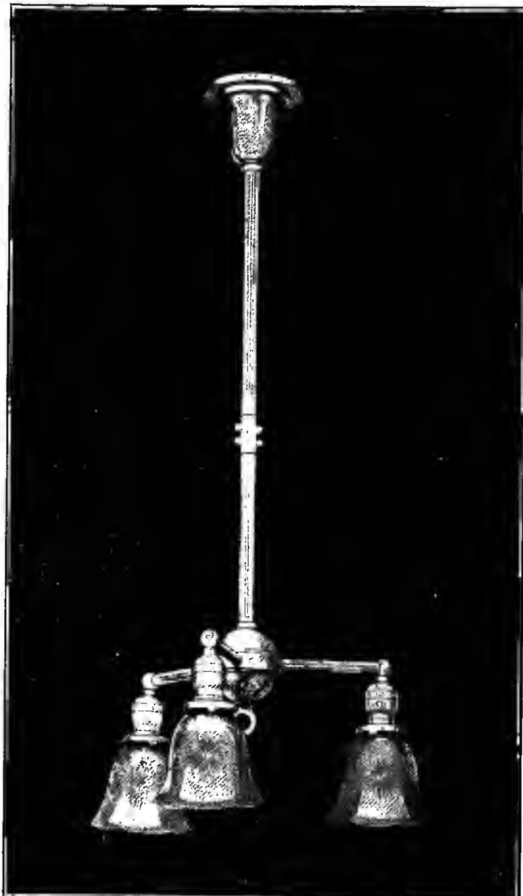

Fig. 4.

The stock sockets are polished brass and stock snap switches are generally enclosed in nickel plated shells. But the sockets may be finished at little expense in brushed brass, antique copper, oxidized copper and other effects.

Porcelain enclosed snap switches give a good effect on the walls and are kept in stock by most dealers.

Details of Installations. The actual details of different installations will vary owing to personal requirements, the amount of money available and other considerations. The general rules common to all installations will be considered, and it will be endeavored to show by a series of specifications and explanations how an installation of any size may be figured.

Ampere Hour and Lamp Hour. In order to estimate the capacity needed for a given installation, a clear understanding must be had of the terms ampere hour and lamp hour.

One ampere hour is one ampere flowing for one hour and likewise one lamp hour is one lamp burning for one hour. As has been stated before, the ampere hour is the basis upon which the storage batteries are compared as to capacity. The total ampere hour discharge is the normal discharge rate in amperes multiplied by 8 hours, which latter is the normal time for a discharge.

For example, a cell capable of giving out five amperes continuously for eight hours would be a forty ampere hour cell.

Capacity of the Battery. To estimate, therefore, the capacity of cell needed to supply a given number of lamps three points must be clear. First, the number of lamps, second, their current consumption in amperes, and third, the number of hours they are required to burn before the battery can be recharged.

The number of hours they are to burn each night may be figured as follows: Note, that the allowance per room for light can of course be decided by the reader as personal requirements vary. The examples in this book are figured variously merely to illustrate the method of figuring.

Consider a house with 8 rooms of which 7 are to have one 8 c. p. lamp, and one room to have two 8 c. p. lamps. The total number of lamps will be 9, and as each requires 1 ampere hours per hour of burning, the total for the 9 lamps will be 9 ampere-hours. But they will rarely or perhaps never burn all at the same time and so an average burning per lamp per night must be estimated. There is, of course, no hard and fast rule to use in this calculation, but from a series of investigations which have been made, it is possible to form some idea.

Dining room lights will probably burn only during meal times and for a short time before and after.

Kitchen lights may burn as late as 10 o'clock, but not as a rule, whereas, the lights in the sitting room will burn longer or at least as long as any of the lights in the house.

Figuring along these lines the following tabulation gives an average of the lamp hours for each night:

1 kitchen, 4 hours	4 hours
4 bedrooms each 1 hour, total per night	4 hours
Sitting room, 2 lamps, 5 hours each	10 hours
Other lights	2 hours
Total	20 lamp hours

Twenty lamp hours at 1 ampere per hour will be 20 ampere hours, therefore, the battery must have a capacity of 20 ampere hours for each night.

But as it would be inconvenient to charge every day, a battery having a capacity of 80 ampere hours would last 4 nights and permit of charging the battery twice a week. Sunday generally using more light than a week day, will consequently need more current.

Some estimators figure a straight 3½ hours per lamp installed, per night.

For an extreme northern climate where the twilight is long, such an allowance is at least large enough and would be probably too much. In country places the average time spent indoors in the evenings is greater than in the cities, because in the latter, there are more and cheaper places of amusement where the masses go, and consequently there is less need for much illumination in the homes.

The size of the family, their social duties, the frequency with which they entertain will all tend to change any arbitrary method of estimating.

Each person installing the plant should be able to form some idea of the lamp-hours after studying the illustrations given here and after having done so, know pretty closely what the probable requirements will be. But in all cases it is best to allow plant capacity enough, for a sudden and unexpected drain upon it might seriously injure it or at least so run the voltage down as to result in dim lights.

Number of Cells. Now as the capacity or ampere hours of the battery will determine the size of the cells, the required voltage will determine the number of cells. In order to make the outfit as simple and as small as possible, the first few specifications will be figured at a voltage of 10.

The power or watts required by a lamp of a given candle power is the same whether it be impressed at high voltage or low voltage. If a high voltage is employed the amperes per lamp will be less than if the voltage be lower. For example, a 10 watt lamp taking 1 ampere at 10 volts would only need 1-10 ampere at 100 volts, the watts being in each case the same.

It is an advantage where there is a large power to be carried, to use a high voltage as the amperes being lessened, the size of the wire is also lessened, which is often a considerable saving.

In the following three specifications the number of lamps is small and the amperes also small, so it will be quite feasible to employ a low voltage, namely, that of 10 volts.

Specifications. The first specification is for 6 lights each of 8 c. p. and 10 volts, but the battery has really 6 cells giving 12 volts, in order that there be a reserve voltage to be employed as the cells run down or become exhausted.

It is about the smallest installation worth wiring for and has been laid out in a very simple fashion, the lamps being only located in very necessary places.

It must always be remembered that any number of lamps may be installed, providing no more be burned at one time than the specifications call for.

The battery has been figured to require charging twice a week, but if more light is needed, then the charging must be just so much oftener. For example, if 20 ampere hours be used up in supplying the lamps for 20 lamp hours each night, then the battery would have to be charged every two days as its total capacity is only 40 ampere hours. Or larger cells would be necessary.

The generator voltage is set at 20, but a trifle under this figure would answer.

House Wired for Six Lights. Location of lights. Two in sitting room. One each in kitchen, two bedrooms and bathroom.

Probable burning of lights.

2 lamps 4 hours each.
2 lamps 1 hour each.
2 lamps, few minutes. 10 lamp hours.

Lamps. 8 c. p. 10 watts. 10 volt. 1 ampere.

Note.—10 lamp hours at 1 ampere per hour would require 10 ampere-hours of current. As charging is to be twice a week, the cells should have capacity sufficient for 4 nights or 40 ampere-hours.

Battery. 6 cells, 40 ampere-hours. 12 volts.

Generator. 20 volts. 8 amperes. 160 watts.

Power about ½ horse power.

Charge. 5 hours twice a week.

Note.—Probable maximum current on the wires will be 4 amperes, and the average current will not exceed 3 amperes.

Wire. From Generator to Battery No. 12 B. & S. Rubber covered copper.

From Battery to outlets. No. 12 B. &. S. Rubber covered copper.

From outlets or for short branches. No. 14 B. & S. Rubber covered copper.

Main Fuse. 6 amperes, to take care of the wires when all the lamps are burning.

House Wired for Ten Lights. Location of lights. Two in sitting room, two in dining room, one each in kitchen, three bedrooms, bathroom and hall.

Probable burning per night.

2 lamps 5 hours each.
2 lamps 1 hour each.
1 lamp 4 hours.
4 lamps 2 hours in all. 18 lamp-hours.

Lamps. 8 c. p. 10 watts. 10 volt. 1 ampere.

Note.—18 lamp hours at one ampere per lamp hour would require 18 ampere hours of current per night. As charging is to be twice a week, the cells should have a capacity enough for 4 nights, or 80 ampere hours.

Battery. 6 cells. 80 ampere hours. 12 volts.

Generator. 20 volts. 12 amperes. 240 watts.

Power, about 2-3 horsepower.

Charge. 6 hours twice a week.

Note.—The probable maximum current on the wires will be 6 amperes, and the average current will rarely exceed 4 amperes.

Wire. From Generator to Battery. No. 12 B. & S. Rubber covered copper.

From battery to outlets No. 10 B. & S. Rubber covered copper.

For outlets and short branches. No. 14 B. & S. Rubber covered copper.

Main Fuse. 9 amperes. To take care of the current when all the lamps are burning.

Specifications. The sizes of wire that are given in the specifications are of sufficient size to carry the current without much loss of voltage, and consequent dimming of the light under the following conditions:

The length of wire used between the battery and the first lamp must not exceed 35 feet (for either side of the circuit.)

No lamps are to be placed farther away from the battery than 50 feet, measuring as above.

Not more than 5 lamps of 8 c. p. and 10 watts are to be burned at one time, unless the dimming of the lamp is of no account.

If these conditions are to be exceeded, the size of the main wire must be increased according to the table.

TABLE III

Wiring Table for 12 volt battery.

8 c. p.	Amperes	Distance Feet	Wire B. & S.
1	1	150	12
2	2	75	12
4	4	35	12
5	5	25	12
5	5	50	10
8	8	35	10
10	10	25	10

Distance in feet means from battery to lamp, that is length of one wire.

This table is calculated to give good results, using the regular sizes of wire.

If used for lamps of higher voltage their amperes must first be figured and then the ampere column used.

Full explanations of wiring formulas will be found in the companion book on practical wiring.*

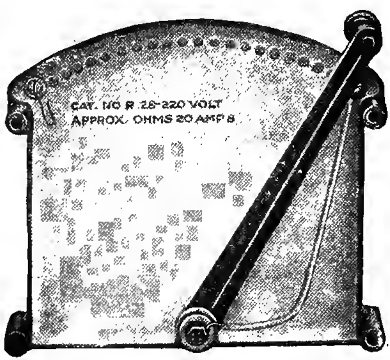

Fig. 5.

Regulator. As the 6 cells will give over 12 volts when fully charged, the lamps would burn too bright if a regulator is not added. Where a

* Schneider, Wiring Houses for the Electric Light with special reference to Low Voltage Battery Systems.

large number of cells is used their number is varied by means of an "end cell" switch, and the line of voltage kept constant. In the present case a simple regulator or rheostat is employed, which, being put in series with the main current dissipates some of the energy and thus reduces the voltage.

For the 6 cell battery a suitable regulator will be the Ward-Leonard Type R. adjustable rheostat, Fig. 5, having about 2 ohms resistance, with a handle making it ajustable in 10 to 12 steps and costing perhaps $4.00.

A chapter might be written upon the way to make a suitable rheostat, and even then the results would probably be more unsatisfactory in labor and expense than would be obtained by the purchase of one as above.

Launches and Yachts. The safety and convenience of electric light on even small yachts and launches cannot be overestimated. Many attempts have been made to make small portable outfits with primary batteries, but for reasons before given, they are not successful.

Most of the plants described are suitable for marine work, in some cases requiring slight changes, however, that would suggest themselves. For a comparatively small boat, sealed or portable type batteries would be necessary on account of the pitching or rolling of the craft.

Launches of 16 feet in length and upward would be well supplied with one of the 12 volt outfits, using a portable battery, the generator perhaps being driven from the main engine by means of a belt or a friction wheel. In this case an automatic regulator would be needed to cut in or out the generator, as the propellor was speeded up or down.

Many of the manufacturers can supply small generators adapted for friction drive if preferred on account of needing less room, but a separate engine would be the ideal means of driving the generator. The general directions for estimating the installation and operating the battery will apply here as in stationary work with such modifications as will suggest themselves.

Larger Installations using higher Voltage. - As the labor and expense of properly wiring the house is the same for any voltage up to and including 110 volts, if the house is to be wired according to the usual practice, using standard fittings, standard wire and accessories, there are several reasons why the battery should be increased in voltage and lamps of a higher voltage also used.

For summer bungalows and cottages or for summer tents, the 12 volt battery is well enough, but for the case where the house is to be used all the year and a reasonable amount of usage given the battery, then the 12 volt system is too low.

In larger houses or where more than 4 or 5 lamps are likely to be burned at one time it is advisable then to use a higher voltage. As the electric light companies are installing systems using low voltage lamps and compensators which reduce the voltage of the house service from 110 to 27½ volts, this latter voltage may be adopted on account of the lamps being a stock article.

In order to secure this voltage up to the last period of the battery discharge, the number of cells should be 16. This will give 33 volts when the cells are freshly charged, falling to 27 volts at which point charging must be recommenced. The lamps will consume the following amperes:

TABLE IV

Amperes per lamp at 27½ volts.

8 c. p.	10 watt	.36 ampere
16 c. p.	20 watt	.72 ampere
20 c. p.	25 watt	.9 ampere

As will be understood, increasing the number of cells for the same total output of power or lights decreases the size of each individual cell, the amperes being lessened as the volts increase.

From the last table it will be seen that the 27½ volt, 10 watt lamp takes .36 ampere as against 1 ampere for the 10 volt, 10 watt lamp, the voltage being practically trebled reduces the amperage to one-third.

TABLE V

Amperes per lamp at 32 volts.

8 c. p.	10 watt	.313 ampere
12 c. p.	15 watt	.469 ampere
16 c. p.	20 watt	.625 ampere
20 c. p.	25 watt	.781 ampere

Specifications for Higher Voltage Lamps. In the following specifications, the hours of burning may be slightly increased because, as the plant will need to be larger to accommodate the increased number of lights burning at one time, and the cost being somewhat greater, it is conceded that the person installing it will wish to use it more freely.

Furthermore, the reason before given applies, that of varying the personal factors in order to illustrate the manner of figuring the data.

House Wired for Ten Lights. Location of lights. Three in sitting room, 2 in dining room, 1 on porch or hallway, 1 in kitchen, 1 in bathroom, 1 in each of 2 bedrooms. If desired another can be located in the cellar, or on the back porch.

Probable burning of lights per night.

3 lamps 5 hours each.

2 lamps 1 hour each.

1 lamp 4 hours.

Balance 4 hours, in all 25 lamp-hours.

Lamps. 8 c. p. 10 watt. 27½ volt. .36 ampere.

Note.—25 lamp-hours at .36 ampere per lamp hour would equal 9 ampere-hours of current per night. As it is planned to charge twice a week, the cells should have a capacity for 4 nights, or 36 to 40 ampere hours.

Battery. 16 cells. 40 ampere hours. 32 volts.

Generator. 40 volts. 6 amperes. 240 watts.

Power. One horsepower, ¾ will suffice if generator is efficient.

Charge. 7 hours twice a week.

Note.—The probable maximum current on the wires at one time will be 5 amperes, and the average rarely exceed 3 amperes.

Wire. From generator to battery. No. 12 B. & S. Rubber covered copper.

From battery to outlets. No. 12 B. &. S. Rubber covered copper.

From outlets and short branches. No. 14 B. & S. Rubber covered copper.

House Wired for Fourteen Lights. Location of lights. Three of 16 c. p. and 20 watt in the sitting room, 2 of 16 c. p. and 20 watt in the dining room, 1 of 16 c. p. in the kitchen, 1 of 8 c. p. in the bathroom, 1 of 8 c. p. in the hall upstairs and another similar downstairs, 1 of 8 c. p. in the cellar, and 1 similar on both the back and front porches, 2 of 8 c. p. or 1 of 16 c. p. in one bedroom and 1 of 8 c. p. in each of three bedrooms. The total lights will be then 8 lamps of 8 c. p. and 6 of 16 c. p.

Probable burning per night.

3 16 c. p. in the sitting room for 5 hours each.

2 16 c. p. in the dining room 1 hour.

1 16 c. p. in the kitchen 4 hours.

A total of 21 16 c. p. lamp hours.

2 8 c. p. in the hallways for 5 hours each.

1 porch light 8 c. p. for 4 hours.

The remainder of the 8 c. p. lamps say, in all 8 hours.

Making a total of 22 8 c. p. lamp hours.

Now 21 16 c. p. lamp hours at .72 amperes each per hour would total 15 ampere hours and 22 8 c. p. lamp hours at .36 ampere each per hour, would total say 8 ampere hours, making a grand total for the evening of 23 ampere hours.

As the charging is to be twice a week as before, the battery would have to deliver 23 ampere hours for 4 nights, or 92 ampere hours, the nearest stock capacity being 100 ampere hours.

Battery. 16 cells, 100 ampere hours. 32 volts fully charged.

Generator. Say 40 volts. 15 amperes. 600 watts.

Power required. One and one-quarter horsepower.

Charge. 7 hours twice a week.

Wire. No. 12, or better No. 10 B. & S. Rubber covered for the mains.

No. 12 for the branches.

Main Fuse. 10 ampere would answer.

NOTE.—Plans and specifications covering all the details necessary for an installation of any capacity can be furnished through Messrs. Spon & Chamberlain.

CHAPTER IV

THE ELECTRIC PLANT

The Electric Plant in General. In the preceding chapters, the storage battery has been discussed together with the method of estimating its size, and also the details of the installation of lights and switches. There now remains for consideration, the selection and operation of all the parts which go to make up the complete plant.

Although there may be a choice of motive power, a generator to furnish the current is of course necessary in any case, no matter how it be driven, the generator and its accessories will therefore be first considered.

The Generator. There are two kinds of electric currect, direct and alternating. The **direct current** alone is suitable for charging a storage battery. Where alternating current only is available, it must first be rectified or changed to direct current before being allowed to flow into the battery. As the generator to be used will give direct current, no further attention need be paid to the alternating current or its handling.

In the first place the generator must have a voltage higher than that of the battery to be charged, or the battery will have to be divided into smaller batteries and charged a part at a time.

The data given in the specifications shows the excess that the generator voltage should show above that of the battery. Some operators figure that the generator should have a voltage of 2.75 for each cell to be charged, that is, a battery of 10 cells would need a generator voltage of 27½ volts to charge it. This is about what has been allowed here, but a slight excess voltage on the part of the generator is no detriment and rather the other way, as by means of the dynamo regulator or rheostat, the voltage can be adjusted satisfactorily.

The amperage of the generator will determine the time taken to charge the battery, it should be at least equal to the discharge rate of the battery, figuring 8 hours to the discharge. If the battery rate of discharge is 10 amperes per hour for 8 hours, the generator would take about 9½ hours to charge it at 10 amperes per hour, for there is always a loss.

The amperage of the generator will then be based upon the charge rate of the battery which is always stated by the manufacturers, and the time in which it is required to attain its full charge. Where the generator is belted from an engine which is doing other work, the charging may be carried on all day at a low rate. On the other hand where the engine must be run solely to charge the battery, the case is different and depends upon the time allowed.

The generator must be what is called shunt wound, that is the wire winding on the field magnets must be of fine wire only.

Where only a compound wound generator is available, a switch or some other means must be provided to short circuit the coarse or series winding, or the battery current would at some time reverse the generator. This would occur upon starting the charge, or, perhaps, when the engine slowed down and the generator voltage fell below that of the battery.

Even if it failed to do serious damage, the reversal of current would probably reverse the polarity of the generator itself, making the positive pole where the negative pole was and vice versa. This would entail much trouble or changing of connections.

Power Required for Generator. In estimating the power necessary to drive small well designed generators, an efficiency of not exceeding 60 per cent. may be allowed for those above one-half kilowatt and not over 40 per cent. or less for generators below one-half kilowatt.

TABLE VI

Power required for Generator.

Actual Watts	Amperes At 12 Volts	Amperes At 30 Volts	Actual h.p.	Nearest Engine h.p.
150	12.5	5	.5	½
225	19.	7.5	.7	¾
300	25.	10	.86	1
450	....	15	1.12	1¼
600	....	20	1.5	1½
750	....	25	1.7	1¾
1000	....	33	2.3	2½
2000	....	66.	4.5	5
4000	....	....	9.	10

This table is figured on actual results using generators whose efficiencies ranged from 40 per cent. to 60 per cent. according to the size.

For cheaply built generators the efficiency to be expected will probably run lower and more power will be required to obtain the full rating of the machine, or the same power will only produce low voltage.

The Switchboard. Upon the switchboard is mounted the apparatus which controls the electric part of the plant and also indicates whether the voltage and current are correct. It is generally a marble or slate slab supported on legs or held out from the wall by iron brackets.

The two principal switchboard instruments are, the voltmeter which indicates the voltage or pressure of the generator, and the battery, and the ammeter which indicates the current flowing in amperes. A switch controls the passage of the current between the generator and the battery, while another switch controls the current to and from the lighting circuit. Or a special switch may fill both functions. The switchboard can also be arranged so that the generator will run and add its power to that of the storage battery giving greater capacity for special occasions. Fuses of lead wire prevent the flow of excessive current by melting and opening the circuit at some stated point.

A device called a circuit breaker must be installed to prevent the battery current from flowing back into the generator when the engine stops or slows down sufficiently to lower the voltage of the generator below that of the battery. It must be reliable as it is actually the brains of the battery. The circuit breaker may be either an electro magnetic affair or an electrolytic cell as used by the American Battery Company, which by chemical action, allows the current to flow one way, but prevents its flow in the opposite direction.

Automatic Circuit Breakers. The automatic circuit breaker shown in Fig. 6 is made by the Ward-Leonard Electric Company.

As the battery becomes charged, its voltage rises and gradually attains a closer value to that of the generator. The charging current naturally decreases as it is dependent upon the superior voltage of the generator. When the amperes are reduced to the value for which the breaker is set, it opens automatically and thus protects both the generator and the battery.

As has been before stated, the circuit breaker is the brains of the battery and must be reliable.

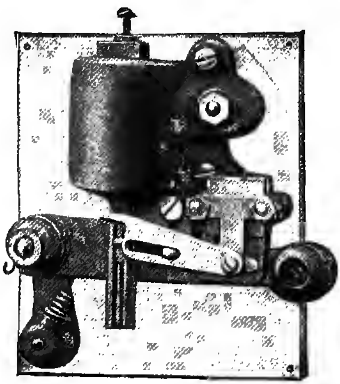

Fig. 6.

Automatic circuit breakers for switchboards are also made by the Elbridge Electrical Manufacturing Company, of Elbridge, N. Y.

There should be also a rheostat which is used to regulate the strength of the generator field magnets and thereby the voltage.

When the handle of this rheostat is moved one way it cuts in resistance into the field magnet circuit, and by thus decreasing the amount of current flowing through the coils, decreases the magnetism. The field magnetism becoming weak has less influence on the armature and the voltage drops. The reverse takes place when the handle is moved in the contrary direction, the point when all this resistance is cut out being the one when the generator will give its highest voltage.

When fully charged the battery will be much higher in voltage than the lamps and it is necessary to have some means of adjusting this voltage. It may be done with a rheostat as in the case of the small 12 volt battery, but for a larger plant this means is wasteful of energy. The simplest way is by the use of an "end cell" switch which controls several cells of the battery, cutting them all in during the charging, but cutting out the excess during discharge until they are needed.

Motive Power. There are three sources of power that may be used to operate the generator A gas engine burning gas, gasoline, alcohol or kerosene. Second a water motor or turbine, and thirdly, a windmill. The steam engine is not included here as requiring too much special knowledge and as being too dangerous in the hands of a novice. The gas engine may be bought in almost any size from one-quarter horse up, but the efficiency of the very small sizes is low.

Windmills for Motive Power. In some parts of the country there is enough strong, steady wind to make the use of a windmill possible for driving the generator. As the wind will vary from time to time, some form of regulator is necessary to prevent the voltage rising too high or falling too low.

The simplest form of regulator cuts out the battery when the wind gets either too strong or too weak, while other types regulate the generator itself.

A good description of windmills in general and an electrically equipped one in particular, may be found in "Windmills and Wind Motors," by F. E. Powell.*

It is strange that windmill operated electric plants of this description, are not more common. Now that the power needed has been reduced by the perfection of the tungsten lamp, it is certain that they will become universal in localities where a good wind is to be depended on.

* An excellent little book giving full detail drawings for the construction of several sizes of small Windmills.

CHAPTER V

Some Typical Plants

Manufacturers of Apparatus. While it is desirable to include a few descriptions of standard

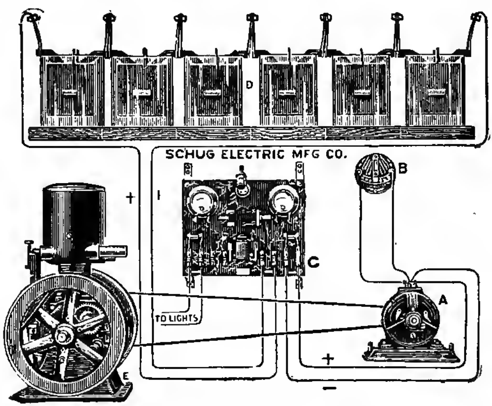

Fig. 7.

apparatus and complete plants, space is limited and the selection must be more or less limited also.*

* Specifications to cover special installations may be obtained through Messrs. Spon & Chamberalin.

The examples have been selected as merely typical of the product of several standard manufacturers.

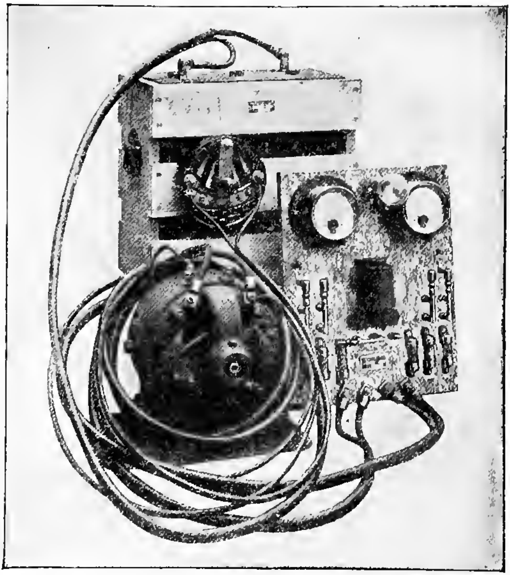

Fig. 8.

In reality the large variety of sizes and styles would require far more space than can be allotted to it here, moreover, much of this data will be furnished by the manufacturers on request.

The Schug Lighting Plant. A complete lighting plant furnished by the Schug Electric Manufacturing Company is shown in Fig 7. The engine is not supplied by them, but only the complete electrical equipment of generator, storage battery and switchboard, in a number of sizes and capacities.

For the 12 volt systems described in a previous chapter, a very suitable outfit, Fig 8, is made up with 6 cells of battery of either portable type or in glass cells, a generator, Fig. 9, and a switchboard.

The generator capacity is 160 watts requiring an actual ½ h.p. to develop it. The battery can be charged in 6 hours at a rate of 10 amperes per hour.

When the battery alone is used it will supply current for 6 tungsten lamps of 16 c. p., for 5 hours, but as the specifications before noted adopt the 8 c. p. lamp as standard, then the hours of light will be doubled with these smaller lamps. Almost 60 lamp-hours with 8 c. p. lamps may be secured with the battery alone.

Operating the generator and battery at the same time will vastly increase the output.

This outfit is particularly adapted to marine work when portable or sealed cells are used.

Other batteries are also supplied to use with the same generator, giving a capacity of 100 and 150 ampere hours each, with charging rates of 10 amperes for 10 hours, and 15 amperes for 10 hours respectively.

The Schug Manufacturing Company supplies larger outfits, giving voltages from 12 to 115, and having battery capacity of 40 ampere hours upward.

Fig. 9.

The American Battery Lighting Outfit. The outfit illustrated in Fig. 10 is supplied by the American Battery Company ,and is one of their

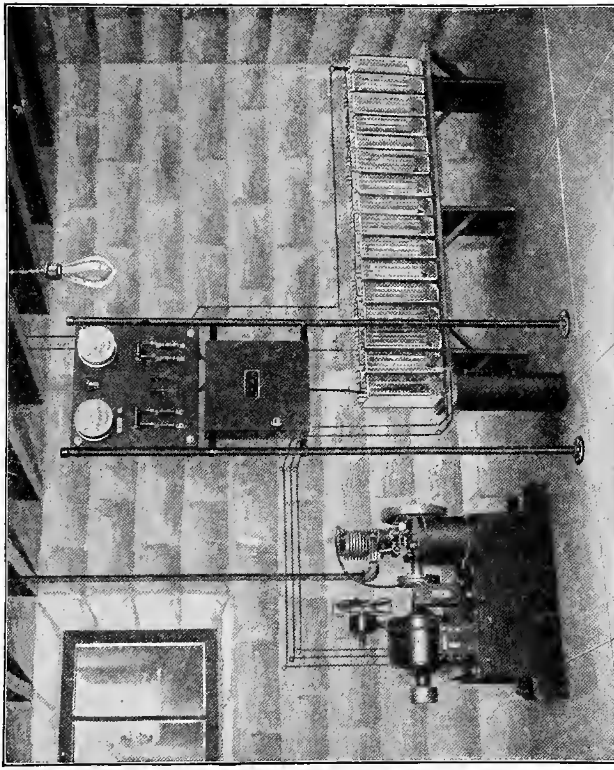

Fig. 10.

standard small plants for low voltage lighting. It consists of a gasoline engine, a generator, a storage battery, and a switchboard on which the electrical part of the outfit is controlled and measured.

The Engine. The engine, Fig. 11, operates on the two cycle principle in which there is an impulse each revolution, giving a greater steadiness than in the four cycle method, where the impulse is only every other revolution.

It is air cooled by means of the fan shown in the cut, entirely dispensing with a water tank.

There are only three moving parts to the engine, namely, the piston, the connecting rod and the crank shaft, there being no valves to stick or create trouble. It will operate for eight hours with a consumption of six quarts of gasoline and one-half pint of lubricating oil, developing continuously one and one-half actual horsepower, at a speed of 900r.p.m. There are two grease cups, but no oil cups to fill and watch as the cylinder lubrication is maintained by the gasoline and oil mixture.

The generator is iron clad as shown in the illustration, thus improving the magnetic circuit and preventing leakage of the lines of force with consequent loss of energy.

The efficiency is high, the output being 7½ amperes at 45 volts, with a power consumption of less than one and one-half horsepower.

Self oiling bearings maintain a satisfactory lubrication not requiring refilling for weeks at a time.

The engine and generator are connected together by a flexible coupling, doing away with a belt and taking up any vibration of the engine which would be transmitted to the generator were a rigid coupling used.

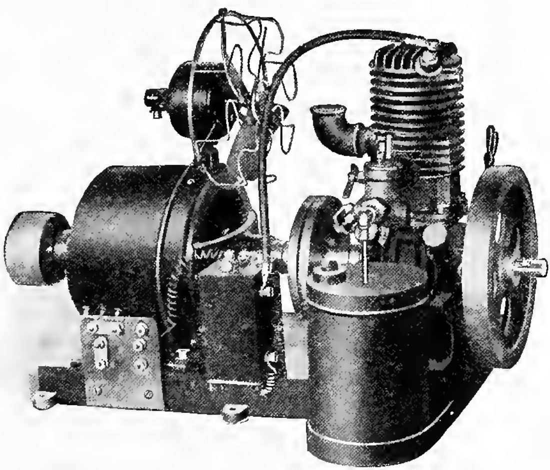

Fig. 11.

To start the engine a switch on the board is thrown and thereby connects the generator to the battery. The generator starting to revolve as a motor, turns the engine and enables it to start without any cranking.

The desired voltage having been attained, the current is passed into the battery and active charging commenced.

The battery consists of 16 cells having a capacity of 40 ampere hours with a rate of discharge not exceeding 5 amperes. The dimensions of the plates are 7 inches by 8 inches and 5-16 thick, the glass jars measuring 3 inches by 8 inches and are 12 inches in height. The complete cell requires not less than 15 inches head room, a strong shelf 5 feet long by 8 inches wide comfortably holding the battery.

The total weight of a 16 cell battery complete, including electrolyte will average 465 lbs., the electrolyte alone weighing about 190 lbs.

The Switchboard. The following instruments and switches are mounted upon a polished black enameled slate switchboard.

Ammeter. Voltmeter. Two point Voltmeter switch. Double pole generator switch. Double pole lighting switch. Single pole circuit breaker switch. Ignitor switch.

The Ammeter and voltmeter measure the current, the two point voltmeter switch enabling readings to be taken from two points on one voltmeter.

The circuit breaker switch controls an electrolytic cell 8 inches by 16 inches in dimensions

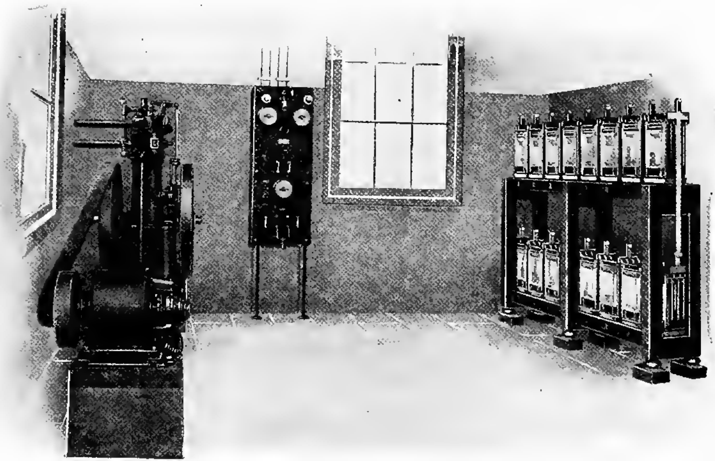

Fig. 12

which contains electrodes and a solution having for its function the prevention of a back flow of current from the battery into the generator at an inopportune time. Should the engine stop, or slow down, the circuit breaker would act and arrest the flow of current FROM the battery, but instantly upon the engine recovering its normal speed would automatically permit the current to flow INTO the battery.

This action is purely automatic and requires no attention on the part of an attendant.

Larger Outfits. The plant shown in Fig. 12, is one of those furnished by the Alamo Manufacturing Company.

It consists of an Alamo 3 h.p. engine belted to a Westinghouse Type R generator of 1¾ k.w. capacity, being controlled from a double paneled switchboard. It is sufficiently large to completely charge the 16 cell Westinghouse storage battery which has a capacity of 15 amperes discharge for 8 hours. A lower rate of discharge will increase the total ampere hours.

The Alamo engines are supplied either in the horizontal type as shown in the outfit in Fig. 13, or vertical types, water cooled and operating on the four cycle system. The governor usually furnished when the generator is to be used for charging purposes, is of the hit and miss type. Although very economical of fuel, this type of governor is liable to cause a slight flickering

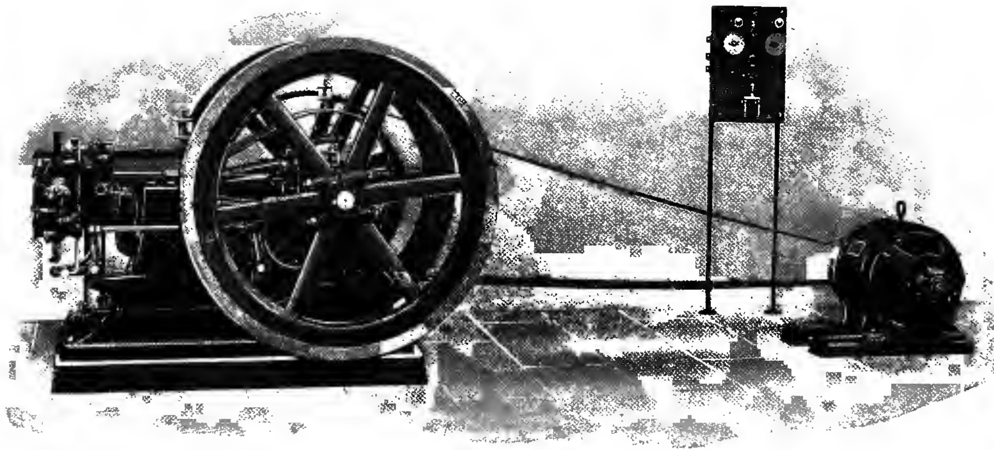

Fig. 13.

of the lights should they be burned directly from the generator without the intervention of the battery. To obviate this, where desired, the engine is supplied fitted with a special throttling governor.

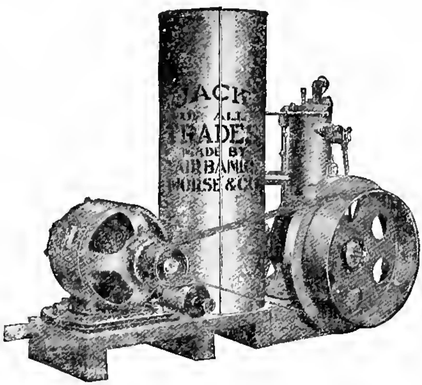

Fig. 14.

The Fairbanks-Morse Outfits. The engines made by Fairbanks, Morse and Company and used in the electric light outfits described here, do not use carburetors or other apparatus to mix the fuel with the necessary air for proper combustion.

The fuel is sprayed direct into the cylinder, a given amount of air being thereby carried in with a given amount of fuel.

The Fairbanks-Morse outfit shown in Fig. 14 is semi-portable, there being a common base for the whole apparatus. The engine is a 2 h.p. standard type T gasoline engine, belt-connected to an efficient generator made by the same com-

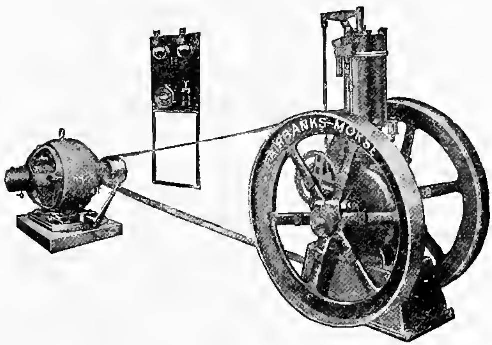

Fig. 15.

pany. It is generally fitted to run with gasoline or naphtha fuel, but if desired can be furnished for kerosene, alcohol or gas. It runs at 400 revolutions per minute, at which speed the output of the generator is .9 k.w.

The tank shown in the illustration may be dispensed with if running water is available for cooling purposes. This outfit is supplied mainly for battery charging, but may be used directly

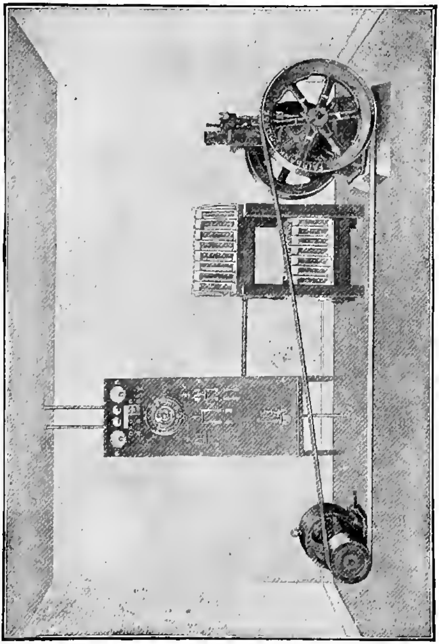

Fig. 16.

for lights if a slight flickering is not objectionable.

Otherwise a Type T Special Electric gasoline engine is furnished as in Fig. 15, which, having a throttling governor, maintains a steadier operation. The latter engine is made in sizes ranging from 2 h. p. at 450 r.p.m. up to and including 12 h.p. at 350 r.p.m., although the port-

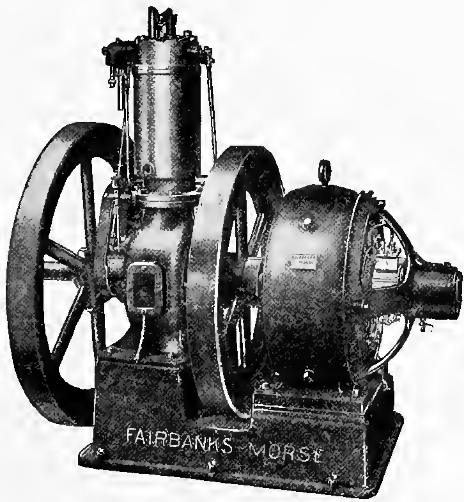

Fig. 17.

able outfits are not furnished in sizes over 6 h.p.

A speed regulation of within 2 per cent. is guaranteed when operating under a steady load, this regulation ensuring a very steady light.

A more complete lighting plant is that as in Fig. 16, which includes a 2 h.p. Special Electric engine and a Fairbanks-Morse generator, together with a storage battery and a fully equipped switchboard.

The generator has a capacity of 30 to 35 volts at 25 amperes, is automatic in operation and regulation, and is self oiling.

The battery is of the Chloride Accumulator

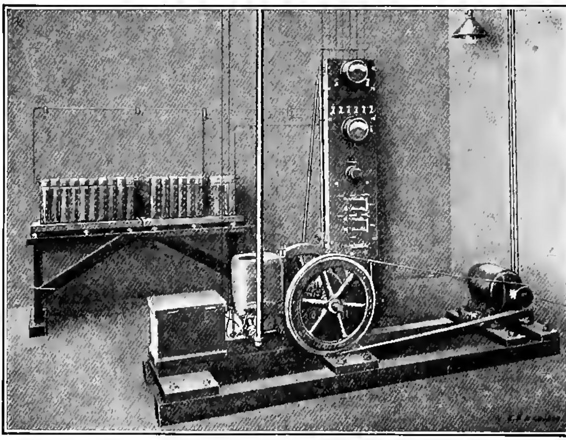

Fig. 18.

type, having a capacity to operate continuously 9 tungsten lamps of 15 watts and 12 candle-power each for 8 hours, or other combinations of lamps in proportion.

The marine finished slate switchboard is mounted on an iron frame and contains the following equipment: Voltmeter, Ammeter, Rheostat

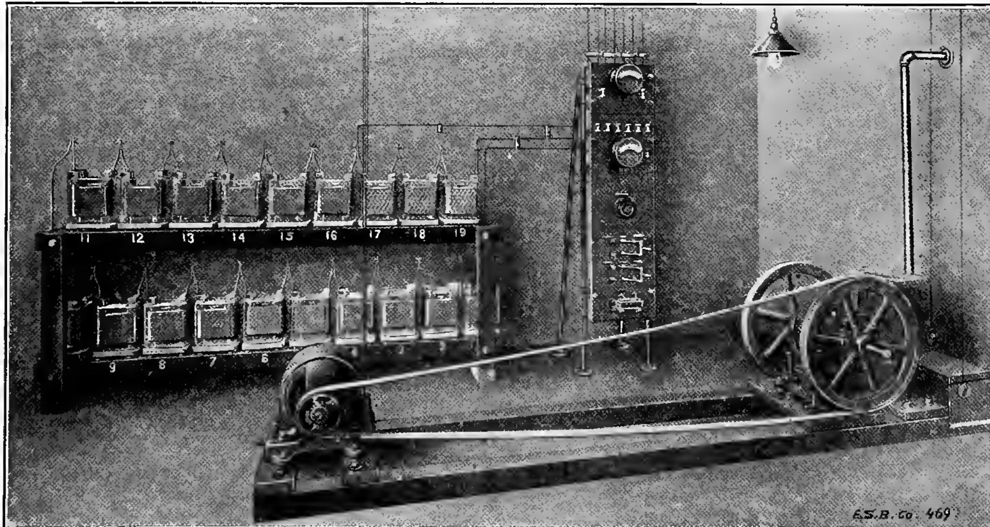

Fig. 19.

for adjusting the generator voltage, generator switch, 2 battery switches, and a circuit breaker.

Lamps and other fixtures also accompany the plant, details of which may be obtained from the manufacturers.

A direct connected generator and engine is shown in Fig. 17, which is more compact than the belted units, but slightly more expensive. These sets are furnished in sizes from 2 h.p. up to and including 12 h.p., the generator output ranging from .9 k.w. to 7.25 k.w. accordingly.

Electric Storage Battery Company Outfit. Two very complete storage battery lighting plants are shown in Figs. 18 and 19.

They are supplied by the Electric Storage Battery Company, of Philadelphia, Pa., and include the Chloride Accumulator for which this company is noted. It is impossible here to treat of the many excellent features of these plants, but it may be stated that they are made in a great variety of sizes adapted to all requirements.

Generator of the Ohio Electric Works. The generator illustrated in Fig. 20, is made by the Ohio Electric Works, and is admirably suited for charging storage batteries or for direct lighting service. As will be seen in the illustration it has a field frame which is designed to give a magnetic circuit of high efficiency with little outside loss, and at the same time is compact and of pleasing design. The workmanship is good and excellent results have been obtained from this generator when used for battery charging. For the latter purpose it is supplied, wound to give 30 volts, but it may also be supplied wound for

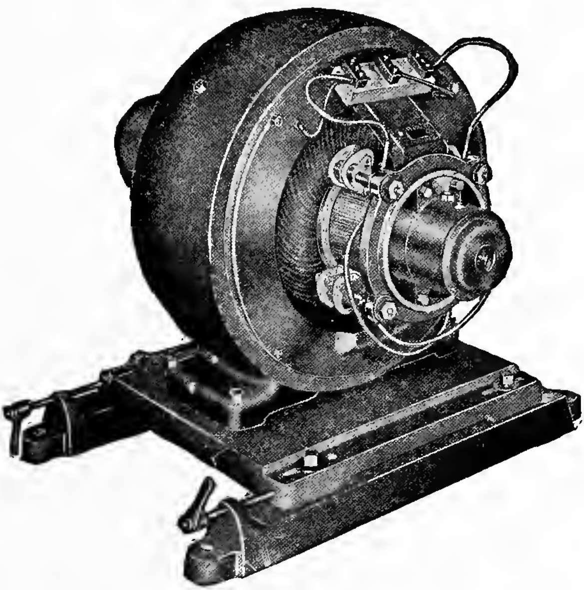

Fig. 20.

other voltages up to and including 220 volts. The small sizes are also well adapted for the lighting of small yachts or launches with the portable storage battery made by the same company and described elsewhere. Rheostat, pulley and slide rails are sent with the generator. The sizes best adapted to the present needs are as follows:

TABLE VII

Ohio Electric Generators.

Watts	K.w.	Speed	Pulley	Actual h.p. needed
750	3/4	1725	3x2	1 1/2
1250	1 1/4	....	4x3	2 1/2
2250	2 1/4	....	4x4	5
3500	3 1/2	....	5x4	7 1/2
5000	5	....	5x5	9

Western Electric Type "I L" Generator. The small generator illustrated in Fig. 21, is made by the Western Electric Company, in a number of sizes ranging from 1/4 kilowatt upwards. It combines compactness and neatness of design with high electrical efficiency, is sturdily built, and has a flared base providing great stability and freedom from vibration.

When supplied for storage battery charging the generator is wound as desired for 30, 35, 42 or 50 volts. This range covers all storage battery equipments used in low voltage lighting.

A commutator with an extra large surface is supplied to provide better brush contact for the increased amperage, thus eliminating sparking and heating.

These generators are especially fitted to operate in damp locations, all of its coils being composed of insulated wire and thoroughly impregnated with a moisture proof insulating compound after winding. Moreover a tight fitting cover will be provided if it is desired to entirely close the generator against excessive dampness or dust.

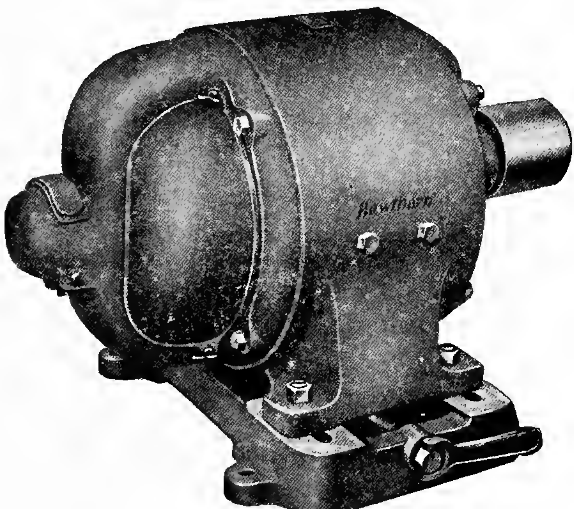

Fig. 21.

A view of a complete generator taken apart is shown in Fig. 22, the most noticeable features being the small number of parts and their simplicity. Oiling is automatic, the self oiling bearings maintaining satisfactory lubrication for

These generators are built for years of hard work, being, therefore, cheaper in the long run than those selected solely on account of their lower first cost.

The normal speeds at 30 to 35 volts for the smaller sizes are as follows:

TABLE VIII

Western Electric Generators.

K.w.	Watts	Amperage at 30 Volts	Speed r.p.m.
.15	150	5	2500
.225	225	7½	2200
.3	300	10	1950
.45	450	15	1950
.6	600	20	1700
.75	750	25	1700

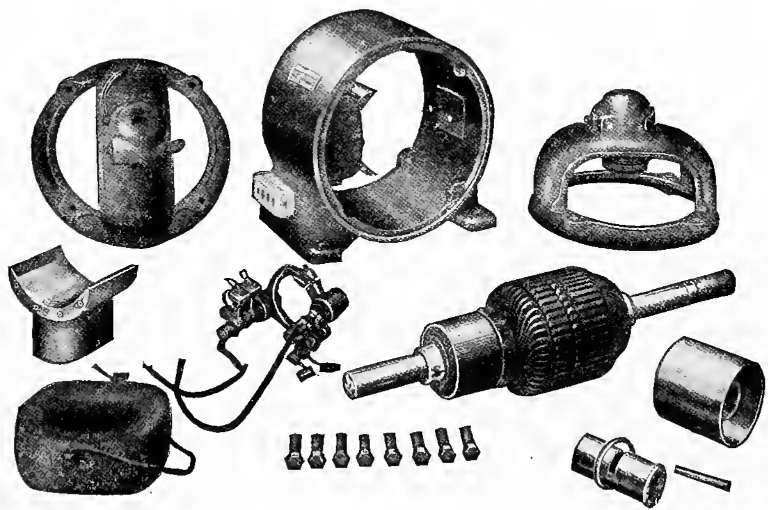

Fig. 22.

CHAPTER VI

Installation and Operation

Installation. Where it is desired to install a plant which has been bought complete from the makers, plans and directions will be sent with the apparatus. Specific instructions cannot be given to cover all cases, as each will differ in some important detail. But a few general directions will be given as applicable to the subject at large.

In the first case a suitable room must be provided for the plant. It should be preferably an outhouse as there is always some noise connected with the operation of a gas engine. If the cellar only is available, then a muffler can be devised to choke off the reports of the gas explosions. As for odors, they would be carried away from a well ventilated room, but it must be borne in mind that the gas given off by a storage battery of the lead-lead type, is corrosive to metal work and irritating, although not dangerous to the human lungs.

Engines and generators must be set level and on solid foundations, as vibration or unsteadiness is very undesirable.

The Battery. Storage battery plates must be handled carefully as they are very brittle. If the battery is shipped unassembled, the separate groups of plates must be first dusted to remove chips of packing and foreign matter. Then the groups of positive and negative plates are interleaved and stood up on end while the hard rubber separators are inserted between them.

The whole combination is then lifted and placed carefully into the jar which should be scrupulously clean. If they are put together correctly, each plate will be of a different color to the next one, that is, every alternate plate will be the same color.

The positive plates will be dark brown or chocolate color, and will, in cells of over four plates be one less in number than the negative or gray plates. In a five plate cell there will be four positives or brown plates, and five negatives or gray plates. They are to be connected in series, that is the grey plates of one cell are to be connected to the brown plates of the next cell.

The manner of connecting will generally be by means of lead covered bolts and nuts, long strips of lead called lugs being brought out from the groups of plates to serve as connecting strips and to keep the bolts away from the acid spray which is thrown off while the cells are charging.

These connections must always be kept dry and free from acid or they will corrode and stop the flow of the current. This is most important and many failures of storage batteries are traceable to corroded connections. In very large cells the lugs are burned together under the strong flame of a hydrogen blow torch.

The cells now being ready and all connected up with all connectors screwed tight, the electrolyte which has been gotten ready before may be poured in.

As it is necessary to begin the charging immediately the electrolyte is in the cells, it should be left out for the present if charging is not to be commenced at this time.

The Electrolyte. The electrolyte or solution used in lead-lead batteries is a dilute solution of sulphuric acid in water. It is made by pouring the acid into the water, **never by pouring the water into the acid,** as an explosion will most probably take place from the intense heat evolved at the mixing. There is always heat when mixing the electrolyte, but the solution is stirred continually until all the acid has been slowly poured in and the mixture is left to cool.

The mixing is best done in an earthen crock and stirred with a glass rod, a stick will answer if absolutely clean and free from any metallic paint. Do not splash the electrolyte on the clothes as it will quickly eat holes in them.

Electrolyte may be bought already mixed, being shipped in glass bottles or carboys holding about 220 lbs. If it is desired to mix the electrolyte and so save on the cartage of the carboys, the acid should be bought pure and at a strength of 1.850 degrees specific gravity. The strength of acid or electrolyte is measured by comparing its specific gravity with that of water which is taken as 1 or as usually written in battery parlance 1000.

A hydrometer, Fig. 23, consists of a thin glass tube with a bulb weighted at the lower end is floated in the fluid. According to the height

Fig. 23.

at which it floats, so will be the density of the fluid, this density being read off by degrees marked on the tube.

The density of the electrolyte should be in most batteries 1200 to 1210 when poured in, but it will vary during the charging and discharging, its variations being an excellent index as to the condition of the cell. When the battery is discharged the density of the electrolyte will be approximately 1175, but will rise during charge. Pure water is to be added when necessary to compensate for evaporation.

It should be emphasized here that the water and the acid must be pure, and the latter especially of the correct quality for the work. It is best bought from the battery manufacturers.

The water must be free from metallic or mineral impurities, distilled water, or clean rain-water caught in a clean wooden or earthenware receptacle being the best. Hydrant water too often contains iron rust or other metallic dirt.

TABLE IX

Showing specific gravity of electrolyte assuming sulphuric acid at 1.850 specifis gravity.

Parts Acid	Parts Water	Specific Gravity
30	70	1225
28	72	1208
27	73	1200
25	75	1180
22	78	1160
20	80	1145
18	82	1130
14	86	1100

Operation of the Engine. Directions for the operation of the engine will be supplied by the makers, but there are some points common to all kinds of gas engines. In the first place, although they are built of metal they require some care.

Every bolt, nut and screw should be looked over periodically, for the vibration of a gas engine will shake them loose in a fraction of the time required by a steam engine, there being more jar.

Oil is necessary on all bearings and moving parts where indicated. It must be remembered that the speed at which the parts move is so high that a part may become heated and severely damaged in a few minutes after its supply of oil ceases. The oil cups should be kept full and examined that they run freely.

Although practice will tell when to fill up the cup, remember that the eye is a better guide than the watch.

Gasoline engines will send smoke out of the exhaust at times. When it is bluish and does not cease soon after the engine is started, it indicates too much lubricationg oil, and the oil should be shut down a trifle. Black smoke with a nasty odor indicates too much gasoline, misfires generally show that the sparking apparatus is not right.

When quite ready to commence charging, see that the main switch between the generator and the battery is open, then bring the engine up to speed. Note the oil cups and whether they are working satisfactorily.

If the voltage is too low as shown on the voltmeter, move the rheostat handle to cut out resistance from the field magnets and the voltage should build up. If it does not, perhaps the engine is not up to speed or the belt is so loose that it is slipping.

Look over the engine and belt and remedy the trouble if it is there.

In most cases there will be no such trouble and the voltage can be regulated satisfactorily.

When the engine is running steadily and the voltage right, close the switch between the battery and the generator and also the automatic circuit breaker and watch the ammeter.

This will show the amperes passing into the battery and must be watched often at first until the operation of the plant is understood, and it is known that the automatic circuit breaker is working well.

If the amperes are too low, raise the generator voltage by the rheostat, if too high lower the voltage in the same manner, only by moving the handle in the reverse direction.

The charging may now be continued until the cells begin to give off gas, the electrolyte becoming full of tiny bubbles which may be seen through the sides of the glass enclosed cells or smelt through the vent holes in the rubber enclosed batteries. If it is a new battery and this is its first charge it will probably take a long charge before any gas will be given off, generally from three to four times as long as it will on subsequent charges.

CONDENSED DIRECTIONS FOR CHARGING.

Assemble cells, place them in position and connect the lugs together.

Connect battery to switchboard.

Pour in electrolyte covering top of plates by about one-half inch.

Start engine and generator.

Test polarity. See that the negative of generator is connected to negative of battery by means of the voltmeter on the switchboard.

Close automatic circuit breaker.

Close switch between battery and generator.

Watch ammeter and regulate the charge by means of generator rheostat.

Battery. The battery when fully charged should give off gas freely in the form of bubbles, and the voltage should read about 2.5 per cell.

When, after having been used for a time the battery shows 1.75 volts per cell, it should be recharged as soon as possible. A storage battery of the lead-lead type must never be left discharged.

Note that the charge reading must be taken while the generator current is flowing into the cell, and the discharge voltage while the lights are burning from the battery. When the battery is neither receiving nor delivering current it will normally show about 2 volts per cell whether discharged or not.

Simple Polarity Test. A simple test without a voltmeter to ensure correct connection between the battery and the generator is the following:

Two sockets are wired with short pieces of wire. Then a wire from one socket is connected to a wire from the second socket. This puts the two sockets in series.

There are now two free wires, one from each socket. One of these is to be connected to the battery, and the other to the generator, which should be up to voltage.

The remaining free terminal of the battery is to be joined to that of the generator and a lamp screwed into each socket. The lamps will light either very dim or bright. If both burn dim it shows that the battery and generator are correctly connected. The sockets and lamps may now be removed and the regular connections made in their place.

If the lamps burn bright, transpose the wires from the generator.

This test, of course, may be arranged from the switchboard at the place where the battery wires join on, in which case the latter may be transposed if necessary.

Care of the Generator. The care of the small generator used in these systems of low voltage lighting is really a very simple matter. In all probability, providing it is started right in the first place, a good generator will run for years with a minimum of attention.

The wearing parts are the shaft, the bearings in which the shaft revolves, and the commutator with its brushes. The bearings should be fitted with self oiling rings, in which case it is merely necessary to keep the oil well filled and see that the rings revolve.

Oil must never be allowed to get into any of the electrical connections such as into brush-holders, brush-holder cable connections, or on the commutator. Where it has crept in it must be carefully cleaned out, or the resistance of the oil will cause heating of the parts and consequent loss of power.

The same applies of course to dirt. Metallic particles are especially injurious to the generator and the copper or carbon dust which may be deposited on the brushes or brush-holders in the course of time, must be removed. It is a good plan to blow out the generator with a bellows every day.

The brushes should bear evenly, but lightly, on the commutator. No oil may be used on the commutator, but in extreme cases a very small quantity of good compound such as Gales', may be used. This will only be needed when there is a slight sparking at the brushes which cannot be controlled by shifting them. At other times the commutator should be kept clean by wiping it occasionally, using a cloth moistened with kerosene.

Provided the commutator be kept clean and smooth, the brushes kept clean and making good contact, and the machine is not overloaded, the generator should run satisfactorily for indefinite periods.

Cost Per Lamp-Hour. Figuring gasoline at 16 cents per gallon or 2 cents per pint, a one horse-power engine would consume 1¼ pints per hour at a cost of 2½ cents.

This one horse-power (actual) would operate a generator, which, at an efficiency of 50 per cent., would deliver ½ horse-power of electricity, that is 373 watts.

This 373 watts costing 2½ cents would operate 37 lamps of 10 watts each for one hour, if there were no loss in conversion of energy. But allowing a loss in charging the battery and the loss of power inherent in the action of all batteries, then the cost of a 10 watt 8 c. p. lamp-hour would average under good conditions 1/10 (one-tenth) cent.

To this must be added a fraction for depreciation of the plant investment, supplies and repairs, but all this should not materially change the result with first class apparatus.

For complete directions on the care of generators, see Schneider, "Management of Electric Power Plants;" Bate, "Principles of Electrical Power."

One-tenth cent for 10 watts is the same as 10 cents for 1,000 watts (one kilowatt), thus comparing favorably with the cost of current in a large city.

But is must be remembered that this figure is only obtained under the usual conditions of a very small isolated plant, where there are no salaries to pay or the many other expenses which would rapidly accumulate in a commercial plant.

WIRING HOUSES

FOR

THE ELECTRIC LIGHT

WITH

SPECIAL REFERENCE TO LOW VOLTAGE BATTERY SYSTEMS

BY

NORMAN H. SCHNEIDER

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PREFACE

Considering all other illuminants, electricity when properly installed is unquestionably the safest. The actual number of fires arising from electricity in dwelling houses is very small indeed and in all cases is due to improper wiring or gross carelessness. Many fires are reported by the press as arising from electricity but it is mostly guess work as upon investigation nearly all have been traced to other causes.

The modern systems of construction and the inspection of all devices used in house wiring has reduced the risk to a matter of personal inattention to the rules laid down by the Board of Fire Underwriters and to the absence of common sense.

In the Low Voltage System now rapidly coming into use owing to the employment of low voltage tungsten lamps and small storage batteries, the risk is still farther reduced.

Good work is as easy to install as poor work although it takes more time and perhaps costs more at first.

With this fact in view the directions given in the following pages are written to illustrate only good and safe work and the rules of the Fire Underwriters have been freely consulted.

The fittings illustrated have been printed from cuts kindly loaned by the Bryant Electrical Mfg. Co., of Bridgeport, Conn., The Tungstolier Co., of Conneaut, O., and H. T. Paiste Co., of Philadelphia, Pa. The balance of the illustrations have been produced from original drawings made by the author and from original photographs, and all rights therein are reserved by the Publishers.

NORMAN H. SCHNEIDER.

Cleveland, O.

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INTRODUCTION.

Before light can be obtained from the incandescent lamp it must be placed in a suitable receptacle or socket and connected to wires leading from the battery.

The socket consists of a shell having insulated contacts of brass, into which the lamp screws and makes connection between its base and the contacts in the socket.

The wires having been attached to this socket convey the current through these contacts to the filament in the lamp and the filament becomes white hot, giving the desired illumination.

It is of vital importance that the wires carrying current shall not touch each other when bared or the current will flow through such point of contact and cause a short circuit which is a sudden rush of uncontrolled current.

Such a short circuit would very likely have disastrous results if not guarded against. This is done by covering the wires with a covering or insulation which prevents the passage of electricity. All metal parts which are to carry current are also insulated either by hard rubber, porcelain or by some other suitable means.

One of the simplest sockets to hold the lamp is shown in Fig. 1 having two short wires protruding from the upper part which are to be spliced or tapped on to the main wires of the circuit. The socket being of porcelain is especially adapted for use outdoors or in damp places. The wires may be of any length desired if specially ordered but usually they are a few inches in length. The copper wire is stranded giving greater flexibility and less likelihood of breaking off when the socket is swayed by the wind.

FIG. 1.

In attaching to the circuit wires, the socket wires are to be bared of insulation for about three inches, scraped bright and twisted on. A good plan is to divide the strands in each wire into two parts, bending them at right angles so as to form the letter T. Then each half is twisted around the circuit wire separately in opposite directions which ensures a good support for the socket and less liability of breaking at the point of connection.

As stated elsewhere all such connections should be well soldered and taped.

Such an arrangement of a weatherproof socket tapped on to a wire is of use in its place, that is in damp locations, but for a dwelling house where something more convenient and ornamental is desired brass sockets are used as illustrated in Fig. 2. These having no permanent wires for ready connection like the weatherproof socket must be attached by means of other pieces of wire, or by flexible incandescent lamp cord.

Fig. 2.

These brass sockets are provided with a key protruding from the side by means of which the current may be turned on or off as desired thus controlling the light. The key operates a switch in the socket, which switch is a device consisting of fixed and of movable contacts through which the current passes when the switch is turned on. Turning off the switch or key separates these contacts and the current can no longer pass until the key is again turned.

Switches are also made in a great variety for location in cases where it is desired to turn on or off the lights without reaching up to the socket. And sockets are made as in the weatherproof socket without keys or switches contained in them.

A combination of wires and lamps with their accessories is known as a circuit.

Circuits. The simplest practical circuit would consist of a pair of insulated wires leading from the battery to a key socket holding the lamp. The key of the socket being turned would either light or extinguish the lamp. The essential parts then of a circuit are the wires to carry the current, the socket or holder for the lamp and the switch or key to control the light. The wires would be insulated, that is, covered with some substance which is not a conductor of electricity to prevent a contact of the metallic portion of the wires and thereby a "short circuit."

In a simple circuit a few feet long the insulation on the wires would be deemed sufficient to protect the wires but where the wires are to be extended for a distance they would have to be supported on insulated supports.

The latter are of glass or porcelain, being generally called insulators, except the porcelain ones, to which the common name of "knobs" is usually given.

Other control of the light than by means of the key in the socket would probably be unnecessary.

Going a step farther a fuse would be added to prevent the copper wire becoming dangerously hot should an accidental short circuit or metallic contact be made. This fuse would be a piece of special lead alloy wire and would melt, opening the circuit when the current became too strong. Lead alloys are used because they melt at a lower temperature than copper without becoming hot enough to do damage before melting. Aluminum wire is also employed for fuses but principally in the high ranges of current. Other forms of fuses will be treated of in their place.

Then another light might be added or perhaps two by means of wires leading from the main wires. These circuits extending for considerable distances and being most probably permanent would be on insulators or otherwise safely supported.

The next improvement would be switches to control the lights and a main switch to cut off the battery from all connection with the wires. The main switch and the porcelain fuse block should be enclosed in an iron box or a wooden one lined with asbestos.

Elaborations will of course suggest themselves such as the installation of more lights, special means of control, fixtures and methods of running the wires to meet special requirements.

It is assumed that a house is ready for wiring and the details of the number, location and size of the lights have been decided upon.

While the scope of these pages is more particularly directed to the wiring for low voltage lighting from storage batteries, the methods described will be suitable for regular 110 volt installations. In the latter case the local rules affecting wiring should be consulted, and if insurance is to be carried, the insurance rules should be consulted. It is impossible to give in a book all the rules which are often different in each State and town. So far as possible all general rulings have been consulted in preparing these directions and the methods to be described are safe.

CHAPTER II.

WIRING A HOUSE.

Before starting to wire a house the plan or specifications should be decided upon showing the number and wattage of the lamps and the location of the lamp outlets. (It is customary to use the term outlet instead of lamp, as for, example, a house would be wired for ten outlets, not for ten lights).

The location of the switches should also be settled as well as the point of entrance for the service, that is where the wires from the electric light mains or battery shall come in.

If a small private plant it may be located in the cellar in which case the main switch or service switch will be in the cellar. But if the plant is located in an outhouse, then the wires must come in the same as those from an electric light company in most cases leading to insulators fastened to the walls at a height from the ground but may lead from there into the cellar if desired.

The exact location should be settled before wiring as all wires to the lighting circuits in the house must run to the service or main switch so that they may be more conveniently controlled.

Material Required. It will be better to read generally through the directions for wiring given here and then survey the job before attempting to figure out what material is required if the operator is inexpert. For this reason much of the description of material has been left to a later chapter and described separately. It then becomes a simple matter to measure with a rule the amount of wire wanted and the other supplies will be in proportion. Of course such things as sockets and switches depend upon the actual lighting requirements.

Laying Out the Job. Suppose it is desired to conceal the wiring in a finished frame house. The first thing is to lay out the outlets or points where the lights are to go and mark the walls or ceiling with a pencil cross at the spot, also marking in the location of switches if any.

Where outlets are required in the centre of a room the ceiling must be marked at the centre spot. This may be done in two ways. The width of the floor is first measured and the result divided in half, a long line than being penciled on the floor at this point, or a stick laid down at right angles to the width of the room. The length of the room is then measured and likewise halved, the place where the half length and the half width meet is the centre of the room. The center of the ceiling may be readily found by means of a plumb bob or a weight on a string held to the ceiling and shifted until the plumb bob hangs directly over the mark.

Where the string touches the ceiling marks the center.

Another and quicker method usually followed by the regular wireman is to procure a stick about half the width of the room in length and standing on a chair or step ladder shove one end of the stick against the wall near the ceiling and mark on the ceiling where the other end reaches. Then put it against the other side of the room near the ceiling and mark again in like manner. This is done four times when the four marks on the ceiling being all of equal distance from the walls can be used to get the exact centre by means of a foot rule.

The stick must be held straight each time parallel to the wall or the measurement will be off. Where rooms are of irregular shape the centre or location for the ceiling outlet may be decided arbitrarily. In the case of a bay window, the latter is not to be taken as included in the dimensions of the room, but is to be ignored.

A long thin bit about one quarter of an inch in diameter and say eighteen inches long is fastened in a brace and carefully driven up through the mark on the ceiling until it comes through the flooring of the upstairs room.

The little hole in the floor will show where to take up the board later on. It is very rare that the center of a floor will correspond with the centre of the ceiling right below it as the upstairs rooms are often laid out differently than those down stairs For this reason it would be very hard to locate the exact spot where the floor board should be removed or the pocket cut in order to get exactly over the ceiling outlet, unless this above method was pursued. The hole bored by the small bit is hardly noticeable in the flooring, except it be looked for.

Where a partition comes exactly over the bored hole, the skirting or mop board must be removed. This is best done by driving in the nails with a nail punch and then lifting off the mop board. If it is attempted to pry it off, it will be surely split and the plaster may come off in patches. But having driven in the nails there is nothing holding the board in place but the edges of the plaster and the fit with the floor.

Having drilled all the outlets and marked where the switches are to go, the next thing is to figure out the easiest and shortest route for the wires. This will not only save labor and mistakes when the work is under way but will enable a list to be made of the material needed.

Taking the case of a two story frame dwelling house with the service or battery plant in the cellar, the outlets on the first floor will be wired through holes or "pockets" cut temporarily in the floor above. The bed rooms may probably be wired from the attic which if not floored will facilitate the wiring operations.

In the first place look which way the floor joists lie and arrange to have as many of the circuits as possible run in the same direction to avoid boring holes transversely through the joists.

This is well illustrated in Fig. 3 which represents a portion of a floor with part of the boards cut away. The joists run in the direction of arrow *B* while the flooring runs like arrow *A*.

If the circuit is to run in the direction of arrow *A*, the joists must be bored and porcelain insulating

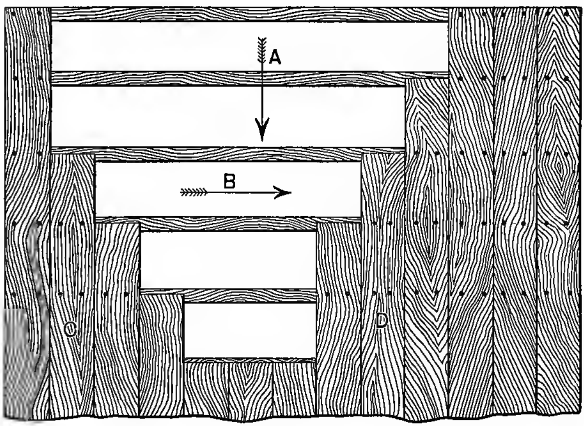


FIG. 3.

tubes inserted in the holes as will be described later. In order to bore the holes in every joist the entire board or two boards covering the route must be taken up.

But where the wires run in the direction of arrow *B* it is not necessary to bore any joists as the wires will lie between them, and the entire board need not be taken up but only a small portion as will be seen later.

Wiring Plans. In the following four plans are shown some typical arrangements of wiring. The

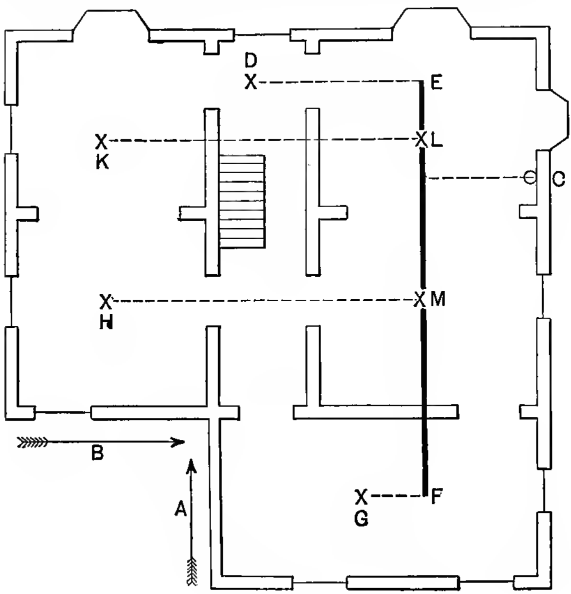


FIG. 4.

plans are those of the first floor and show the outlets of that floor, but the wiring is as it would appear when viewed from the second floor under which it is located.

In order not to complicate these plans no clothes closets, bathrooms or the usual details of house construction are shown. The idea is merely to show in a brief manner the direction which the wiring would take, the two wires being indicated by a single firm line or dotted line.

The arrows indicate the direction of the joists and floor boards, arrow *A* pointing in the direction of the floor boards and arrow *B* in the direction of the joists.

The heavy lines show where it is necessary to take up complete boards and to bore and tube the joists. The dotted lines show where the wires are run between the joists.

It is thus possible to see at a glance the best path for the wires.

The circle *C* is at the place where the wire from the service or main switch will come up in the wall to feed the circuit.

Consider first Fig. 4. The flooring will be taken up between points *E* and *F* in the manner to be described later.

The branch wires to outlets *D*, *K*, *H* and *G* will be joined or "tapped" on to the circuit between *E* and *F* and the wires to the service down the wall at *C* will be also tapped on. This tapping will only require pockets to be taken up at intervals possibly one at *D*, *K*, *H* and *G*, and one or two between *L* and *K* and between *M* and *H*. The point at *C* will probably be opened by removing a portion of the mop board or skirting.

In Fig. 5 is another layout of the same job where it will be noticed that there will be more boards to remove and more boring as shown by the heavy lines.

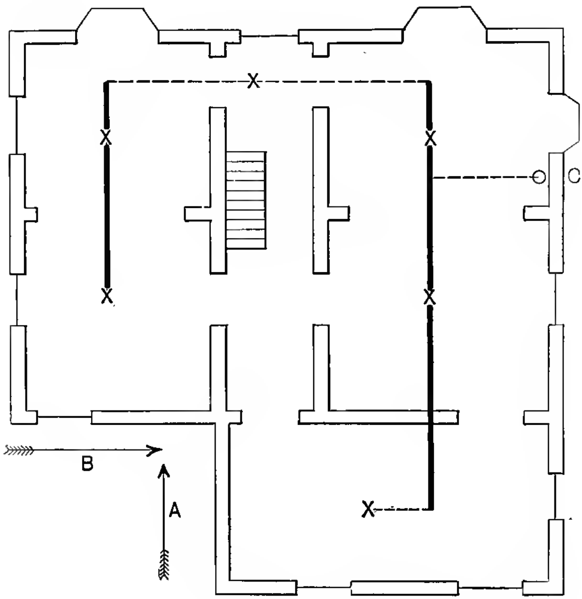


Fig. 5.

The labor is greater in this scheme and nothing is gained thereby.

In Fig. 6 is a plan of another house drawn in the same manner the boards running like arrow *A* and the joists like arrow *B*. Here the boring through the joists will take the direction of heavy lines, but the wires may be continued past outlet *D* and down in the wall to the cellar.

Outlets *E* and *F* and *G* will require branch wires run to them.

In Fig. 7 is another house plan where the wires run in a complete circuit from outlet *F* to outlet *D* and the service wires tapped on at *C* where they go down in the partition. If the partition is not handy the main wires may continue to the point *E* and there go to the service.

Each house presents its own conditions but a little study will disclose the best and most handy route for the wiring.

As the simplest of these circuits, the last one will be considered and the operations more particularly referred thereto although most of the directions given will be general in application.

Pockets. The first operation in wiring will be to open pockets at intervals in the floor or to remove floor boards in order to gain access to the space beneath.

The pockets will be spaced where the knobs are to come and above all outlets in the ceiling.

In order not to complicate the directions at this point, it will be better to read to the end of this chapter before actually cutting any flooring. In this way the exact points where the knobs are to come will be better understood.

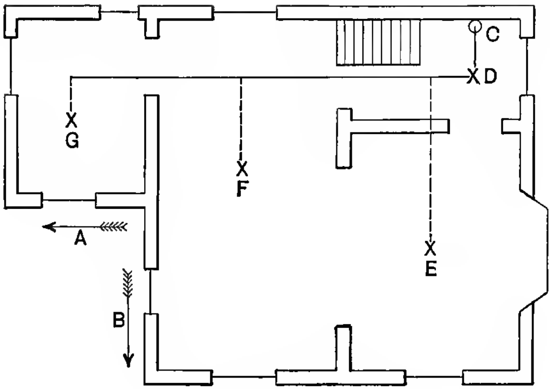


FIG. 6

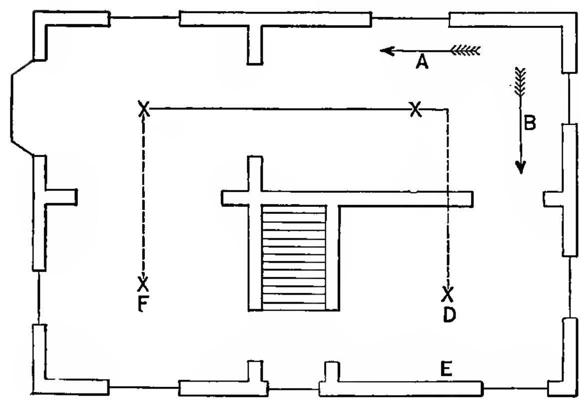


FIG. 7

The exact places where the ceiling outlet pockets are to be taken up will be found marked by the bit which was driven up through the ceiling, but the other points will have to be determined on surveying the route and will be determined by the distance between outlets as is explained in the paragraphs on knobs and their use.

The manner of opening a pocket in a matched wood floor is first to bore a one quarter inch hole for the keyhole saw through the joint between two

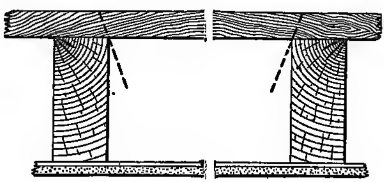


FIG. 8.

boards and as near the joist as possible. The joist may be located by the nails through the flooring.

If blind nailed bore a hole by guess after tapping the floor and locating as near to the joist by the dull sound. Then bend a short length of wire and inserting it through the hole fish around for the joist. A little practice will reveal to the touch the distance of the joist by the resistance to the bent wire.

Having bored the small hole, force in the end of a key hole saw and cut across the board at an angle as shown by the dotted lines in Fig. 8. This is to permit of the board being replaced neatly after the wiring is completed. Having sawed across the piece of board at both ends in a similar manner it may be pried out using a chisel as shown at *B* in Fig. 9. If it be a hard wood floor it is better to saw first down with the grain between the boards cutting off the tongue of the adjacent board as shown at *B*. This makes it easier to pry the

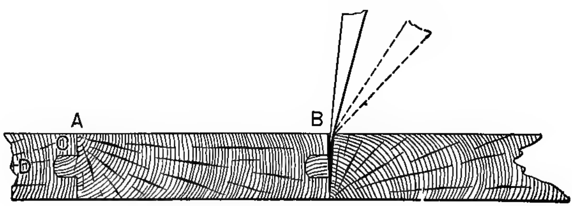


FIG. 9.

board up without splitting off the top tongue *C* of board *D* as would be the case if the chisel were bent down hard at *A*.

When taking up a complete board insert the chisel always on the side *B* and leave a second chisel in to act as a wedge when removing the first chisel to pry at a new place further along. Sometimes several flat wedges or chisels may be used in this manner or an assistant can be of service. Taking up the first board in every case is the hardest, a second adjacent board is easier to take up than the first. Always lay the pieces near the hole from which they are taken or mark them so that they may be put back again. The chisel used should be at least one inch broad and better if it is wider as the distribution of leverage will ensure lighter markings on the edges of the boards.

When all pockets are open and all necessary boards taken up, the boring and tubing of the holes through the joists may be undertaken.

Boring and Tubing. In boring the holes through the joists they should be located about two inches from the top of the joist. As they will be bored from above they will slant a trifle but this cannot be helped and will only require a little more wire and be harder to pull the wires through than if the holes could be bored straight and level.

These holes should be bored with an $\frac{11}{16}$ inch Ford bit or other single cutter bit so that they will accomodate tubes $\frac{9}{16}$ inches outside and $\frac{5}{16}$ inch hole. If a tighter fit is desired use $\frac{5}{8}$ inch bit. It is better to have the tubes fit tight as they will not slip out through jarring or when pulling the wires through them. The latter is usually done so that the pulling wire tends to pull the tube head into the hole and not the other way. The matter of bits is taken up in the later section on tools and material. There will be probably a lot of holes to bore but a clean sharp bit and application will finish the job.

In boring these joist holes an extension is a handy tool, this is a steel rod which fits into the brace and holds the bit lengthening the latter. These extensions may be bought of several convenient lengths.

The two holes for one circuit should not be closer

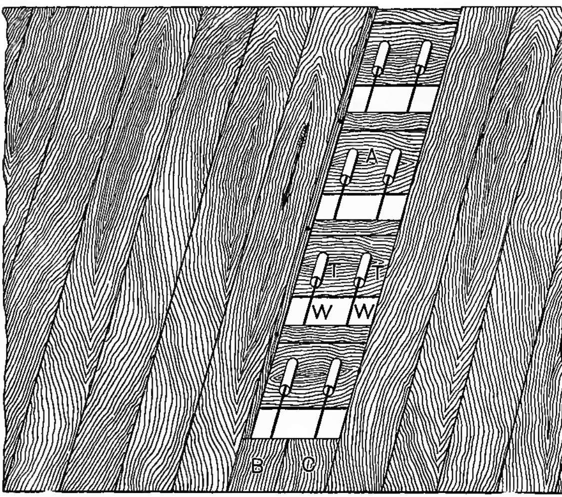


FIG. 10.

than five inches to one another and better if still further apart.

The appearance of a portion of the floor with the tubes and wires installed is shown in Fig. 10.

There being two wires it is necessary here to take up two boards in order to have room enough to work in. *A* is a joist, *T T* two tubes and *W W* two wires while *B* and *C* are the boards continuing those which have been taken up. The wires being pulled in the direction of the arrow pull the tubes into the holes the heads being on the side of the joists not shown. If pulled against the direction of the arrow there is a liability of pulling out the tubes. Of course it is a small job to push them back again but doing so means handling the wires after they have been stretched and this is not to be done more often than is necessary by one inexpert in wiring work.

Where two joists come together as where the end of one overlaps the end of another, a long tube must be used sufficiently long enough to pass completely through both joists. Details such as these will readily suggest themselves to the careful worker who studies the work as it progresses.

Running the Circuits. Having now bored all the holes and tubed those in the joists, place the knobs after which the actual running of the wires may be proceeded with.

Nails and Nail-heads. For fastening knobs to the wood work, screws may be used but stout wire nails are cheaper quicker and satisfactory.

In order to avoid hitting the porcelain with the hammer while driving the nail home, leather nail-heads are slipped on the nail. These are small washers of belt leather and lying under the head of the nail act as a cushion between the hammer and the porcelain. Leather nail-heads may be purchased from any electrical supply store or cut from a piece of old leather.

Knobs and Their Use. The form of porcelain insulator or knob used in this class of wiring is known as the No. 5 or 5½ and is described and shown in the section on materials. What are known as split knobs are also there described.

The general spacing between knobs along the joists is 4½ feet but will vary according to circumstances. The pockets intended for use in placing knobs between outlets are taken up in accordance with this spacing but may vary. Sometimes by extending this spacing a trifle only one knob is needed between two outlets and only one pocket is therefore required.

A study of this condition will save work and knobs but remember not to save labor and material to the detriment of the job. A portion of the floor showing three pockets with the knobs and wire installed is given in Fig. 11.

There is no attempt in these diagrams to give exact distances or measurements as the width of floor boards and other conditions vary.

Wire. The copper wire used in wiring inside the house must be rubber covered and protected by a cotton braid and of the size to be selected according to the data given elsewhere. This wire is suitable to use in moulding or concealed in the flooring when strung between porcelain knobs, or pulled in between walls having first been incased in some form of flexible tube such as Circular Loom or Flexduct.

It must not be used outdoors where it will be exposed to rain or snow but the so-called weather-proof wire with a braided covering used in its

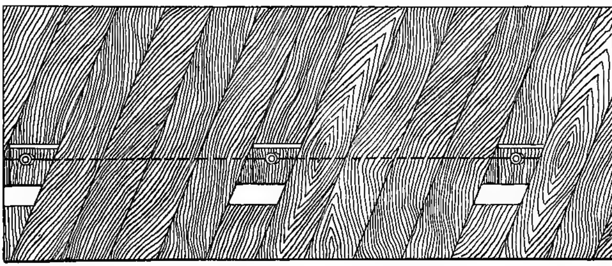


FIG. 11.

stead. Although the latter form of insulation is never as good as rubber yet outdoors it does not crack or rot. It is never run in wood mouldings but is always supported on knobs or glass insulators.

Details of wire are given in the section on materials.

The best method of handling the wire is to take the coil and divide it into two equal coils. This enables both sides of the circuit to be run practically at the same time.

For the present leave these two coils at the point where it is intended to drop the two service ends down in the wall to the service switch in the cellar.

Take two ends from each coil, or one at a time as preferred and with care so that they do not kink, start these ends under the floor through the nearest pocket and under the floor from pocket to pocket and through the tubes until the extreme end of the circuit is reached. Considering Fig. 7, the coils will be left at *D* (or at *E*) and the ends run under the floor past each outlet until outlet *F* is reached. Then making fast at *F*, the wires may be stretched and fastened to the knobs returning along the route until the other end of the circuit at *D* or *E* is reached, there being then the remainder of the wire lying in two coils.

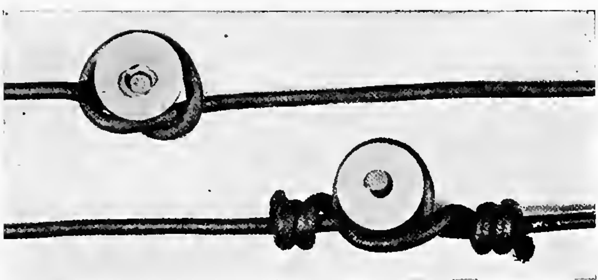
They will not be pulled down into the cellar at *E* yet but at a later time as will be seen farther on.

The ends at the farther ceiling outlets *F* may be left long enough to pass down through the ceiling hole and leave at least 8 inches for connection to the fixture.

On straight runs or when running one circuit it is a good plan to place all the knobs first then the wires can be pulled tight from the extreme end knob and fastened to the knobs as the circuit is followed.

The run will be past each outlet as far as possible but no outlet wires will be tapped on yet, this will be done when the entire length of wire has been fastened under the floor to the knobs.

Making Fast. When making fast from knob to knob the wire may either be given a turn around the intermediate knobs being held tight at the end knobs by a dead-end hitch or what is better be



FIGS. 12 and 13.

hitched at each knob as shown in Fig. 12. This takes more wire and a little more practice but keeps the wire tight between all knobs instead of only between those to which it is dead-ended or hitched. The principal objection to these methods as against tie wires is that should the wire come off the knob the hitched or twisted part would slacken and allow the wire to touch the woodwork.

A good method is to fasten a few knobs on a board and practice the hitches and other methods of securing wires the advantages of the several methods will then be apparent and the practice useful when actually engaged in wiring up the house.

The method of tying a wire to a knob using tie wires is shown in Fig. 13 from a photograph. The tie wire is a separate piece about fifteen inches long and is first tied around the knob and main wire so as to secure the latter to the knob. The loose ends are then twisted around the main wire one end on each side of the knob. The hitch or tie is made by using the middle portion of the tie wire leaving two ends of about the same length.

Another method which is not so good is to merely wrap the tie wire around the main wire and the knob and twist on the ends. The hitch although taking more wire and more time is to be preferred in all cases.

Where a circuit ends at an outlet two methods may be pursued. The wires may be dead ended and short pieces for the outlet be tapped on, this makes a firm job but requires a soldered joint. Or the ends of the wire may be left long enough to reach down through the outlet after the wires have been stretched and made fast by means of the dead-end method elsewhere illustrated. The latter is the usual method where the wires can be ended near the outlet but sometimes it is not practicable to end them near the outlet.

Where two circuits cross each other or where one wire of a tap crosses the other main wire, a porcelain tube should be slipped over the crossing wire or wires as shown in Fig. 14. There should be placed two knobs each side of the crossed wires as shown in order to secure the crossing wire and the tubes. These knobs are often omitted and the tubes merely held fast to the wire upon which they are slipped by means of tape but the above is preferable.

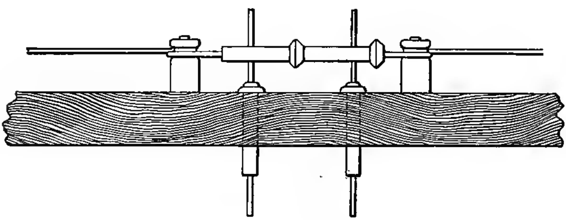


FIG. 14.

All branch or tap wires must be secured to a knob at the point where they are led off from the main circuit as at outlets, these knobs however need not be installed now but when making the taps.

Joints. The two joints used in electrical wiring are the splice and the tap. The splice as its name implies is used where two pieces of wire are to be joined together in the direction of their length. The tap is used where a branch wire is to be run off another wire at right angles to it.

There are two methods of making splices, by twisting the wires together and by using patent screw unions or Dossert joints. Taps are also made by twisting one wire on to the other or by Dossert taps. Furthermore there are several pieces of apparatus such as fuse blocks and cutouts

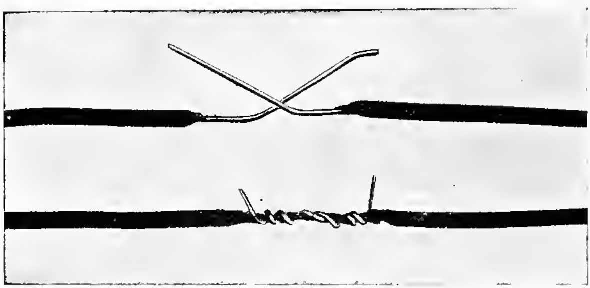


FIG. 15.

in which wires are joined through screw connections or under screwed lugs and several ingenious devices for special conditions.

The first and simplest methods of twisting wires will be described here.

The illustrations showing splices and the methods of fastening wires have been made from photographs of the actual work making the operations clearer than could be done by drawings.

In Fig. 15 is the method of making a splice. The wire is bared of its insulation for three inches and the two pieces laid together and bent as shown. Then the two bare wires are twisted together the ends shown loose being either worked in with the pliers or cut off close. A method often pursued is to twist the wires tighter together each turn lying close up to its neighbor, but the looser twist gives a better means for applying the solder. With

FIG. 16.

the close coiling the solder is liable not to penetrate the wire turns but where the turns are well apart it can enter more readily.

The method of making a tap is shown in Fig. 16 from a photograph. A knob is placed where the tap wire is to lead off from the main wire. The latter is then bared of its insulation a few inches from this knob and scraped bright.

The tap wire is also bared and scraped bright for three or four inches at its end and fastened around the knob so as to hold the main wire to the insulator. This is done by making a hitch with the tap wire while putting it in place. The loose end is wrapped around the insulated portion of the main wire and twisted around the bare spot as shown.

This method secures the main wire to the knob, secures the tap wire to the knob and to the main wire before it gets to the bare spot and takes all strain off the joint and the main wire. The hitch is not drawn tight in the illustration to better show the details of the operation.

In the same figure is illustrated the best method of making a dead-end. This is the end of this circuit and the end of the wire is hitched around the knob, then the loose end wrapped around the tight wire. This is better than merely giving the wire a turn or two around the knob and twisting up the ends.

Soldering. All joints made in wires which are to carry current should be soldered in order to make good electrical contact. Unsoldered joints are both dangerous and unreliable. In the first place unsoldered joints will corrode from dampness and by reducing the bare clean copper surface raise the resistance of the joint so that it may become heated. In the case of 110 volt installations the resistance of a poor joint might not be apparent in the light but where the voltage is low the resistance of the poor joint is a serious matter.

Poor joints are the cause of fires in many cases and it must be impressed here that all joints carrying current must be above reproach. *Remember that an unsoldered joint or any poor work in fact does not improve with time but becomes worse.*

As there will be a number of joints to solder in wiring up a house, it is best to leave them until as many as possible are ready for soldering. It is then a quick job to go from joint to joint and solder up. The soldering torch need not be lighted and extinguished more often than necessary.

The soldering torch used will depend upon what is available unless it is desired to buy one. If none is at hand a small alcohol torch or blowpipe may be bought for about a dollar and will answer all practical purposes. A flame that gives smoke will not do to solder with, alcohol or gasoline used in a proper torch are the best.*

Together with the lamp will be needed some wire solder or shoestring solder and some kind of flux. There are several good kinds on the market called generally " soldering paste " and any electrical or hardware store can supply them. So called soldering salts made of muriatic acid and zinc *should never be used* as unless the last trace has been washed off the joint it will surely corrode in time.

A small quantity of the paste should first be put on the joint which is then heated with the torch

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* *See* Thatcher, Simple Soldering both Hard and Soft.

flame and the solder held to it until it melts and runs thoroughly into all the crevices of the joint. If the wire is not hot and the solder run in well, the joint will be bad and surely cause trouble. Try the first job as soon as the solder is set and if it peels off either the paste was not sufficient or the wire was not hot enough. Soldering with a clean joint, good paste and a hot flame is by no means a difficult process.

Taping. After soldering the joint, or tap, it must be covered with an insulation equal to that removed for a weak spot of insulation at any point is bad.

A few inches of the rubber tape is cut off the roll and twisted tightly around the joint while it is hot. If it has cooled it should be again heated. It will be found that the heat will melt the rubber and it will adhere to the joint to which it is to be moulded with the fingers. Then the friction or adhesive tape is wound over the joint covering the wire entirely from a few inches back of the joint to an inch or so beyond it.

No bare spots may show at any place but all metal must be covered neatly with rubber tape and with friction tape.

Ceiling Outlets. In order to have a secure hold for the screws used in fastening up the fixtures, ceiling boards, *B*, Fig. 17 are placed at every ceiling outlet. A piece of $\frac{7}{8}$ board, soft pine preferably is cut just long enough to fit between the joists *J J* and about 6 inches wide. Wire nails are then driven part way through the board near the edge in a diagonal direction and the board laid in place so that its centre comes just over the small hole made by the bit. It is then nailed fast using great care not to hit it so that the plaster falls from the ceiling *C*.

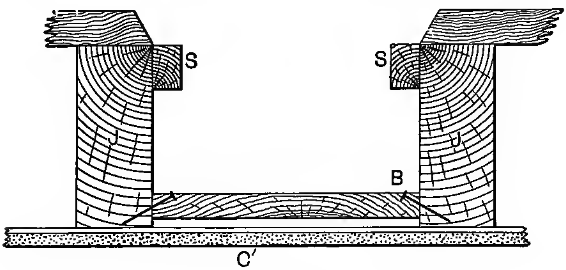

FIG. 17.

It is not hard to fix these ceiling boards if the nails are driven carefully and diagonally, using a nail not over one inch and a half or two inches long. A little experimenting first will show the correct way to nail the board, it is easy after the correct way is learned but pages of directions would not make it any clearer.

Having put ceiling boards in place at every outlet, go down stairs and with the bit used in boring for the tubes, bore up through the ceiling at the point where the small bit went through. Two holes must be bored but each diagonally upwards in such manner that they make two diagonal holes through the ceiling board but only one hole in the ceiling plaster below. The idea is that the two pieces of loom each covering one wire are to start down through practically separate holes in the ceiling board but to come together through one hole in the ceiling. This is shown in a later illustration (Fig. 25).

After studying this out it will be seen to be very simple as the loom is flexible and two ends can be flattened a trifle to come out through one $\frac{11}{16}$ inch hole in the plaster. If the operator prefers he may bore one hole straight up and cut the board away to allow the two pieces of loom to pass through, or bore the ceiling hole first, then make a large hole in the ceiling board before nailing it in place. But the first method is the best and really the simplest.

It may be remarked here that the wires coming down through the ceiling outlets for the fixtures will be separate pieces cut to length and tapped on to the circuit separately except perhaps at the extreme end where enough may be allowed when tying to drop down at this one outlet.

After having installed the ceiling boards, pieces of lumber say one inch thick and two inches wide, are nailed on along the joist just below the opening as shown at *S S*. These pieces are to hold the pieces of flooring when the latter are relaid as is shown in a later illustration (Fig. 25).

Looming the Wire. Having now reached the coiled wire measure enough to reach clear down into the cellar and leave enough additional to reach the switchboard, then cut loom enough to cover the wires from the last knob upstairs to the entrance into the cellar and slip it on the wires. This of course applies to both wires of the circuit.

This loom or "circular loom" is a flexible insulating tube made in several varieties and called by various trade names. Circular loom and Flexduct are the two best known and are suitable for use here. They are costly however and measurements should be made before buying, the average cost being about 5 cents a foot or 10 cents for the two wires.

The wire is inserted in the tube and should be shoved in little by little taking a grip on the wire between the first finger and the thumb a few inches from the opening of the loom. At first the wire will slip in easily but after a while it may stick, when the loom should be shaken as a terrier shakes a rat. If an assistant holds the far end of the loom when feeding in long wires, he can shake it continually and the wire will slip in the more easily. The sizes of loom suitable for different wires are given in the section on materials.

Wiring in Attics. The wiring for the fixtures on the second floor will be done in the attic. Wiring in attics is done with consideration as to whether there is any possibility of the attic being used for other than a space between the roof and the ceiling. Where the attic is too small for other use and there is no possibility of persons entering it except for stringing wires, or where it cannot be used for storage purposes, as in many bungalows, the wiring may be installed on the floor beams without boring or tubing them but by running the wires on knobs. But where there is any possibility of the attic being used the wires should be installed by boring and tubing.

The installation of the wiring for the second floor then will probably be easier than that for the first floor as there will be less cutting of boards and perhaps none. The layout can be made easily as here will be no partitions to obstruct the view and the flooring if any will not be hard wood matched but plain boards.

The ends of this circuit may either be tapped on to the circuit on the floor below or what is better in a large house, run clear to the service and there connected to a separate cut-out or switch, details of which will be given in the section on service switches.

CHAPTER III.

Completing the Installation.

Wiring to the Service Switch. The service or main switch will in the majority of cases be in the cellar or lower part of the house. The ends of the circuit wires which have been measured, cut and protected by loom are now ready to be pulled down for attachment to this switch. This may be done now or after the outlet wires have been tapped on. Whatever will save time labor and going up and down stairs is worthy of consideration and will determine the time for each operation.

In frame houses there will be found a space between the lath and plaster of the walls and the outside boards of the house in which space the wires may be pulled down. Generally this space extends clear from the attic floor to the cellar ceiling and a lead weight called a mouse tied on a stout cord may be dropped clear down to the cellar from above. In some houses where the floor has been laid in continuous lengths the space will be blocked but removal of the mop board and the boring of a couple of holes will remedy this. A joist or "plate" will also be frequently found blocking the way and must be bored.

Having dropped the weight down in this space and secured the free end of the cord to the wires, the weight may be found down in the cellar probably resting on top of the cellar wall and the wires pulled down by its aid.

It is a hard job for a novice to pull wires down alone and an assistant is of service upstairs who can feed the loomed wires down and keep them from kinking while they are being pulled down. It is a peculiar fact that if there is a nail or any projection upstairs any where near the wires while they are being pulled down that they are almost sure to catch on it. The pull should be steady and careful as although the loomed wire will stand a considerable strain there is no need of using more force than necessary.

The wires having been pulled into the cellar are ready for attachment to the service switch.

Where the service is in the attic the weight is to be dropped down in the same manner and the wires pulled up. As this is a harder job, sometimes it is better to pull down a separate pair of wires and tap them on to the main circuit which is first dead-ended.

The Service or Main Switch. Where the battery plant and the switchboard are located in the house the circuit wires will probably be led directly to this switchboard and controlled from it by means of a switch or switches. But if the plant is in another building the wires leading from it will then run to a main or service switch located in the house to which likewise the house circuit wires will also connect.

Considering then that the battery or service wires are run in from outside it is best to install a service switch and fuse block. As also in the case of a large house the wiring will be divided into perhaps two or more circuits, there will be necessary more than one fuse block and if desired a switch to control each circuit. The service wires will run to the service switch and cut-out first. The best plan is to make up a box to hold the switches and fuse blocks.

The size of the box will depend upon what it is to hold of course but it must be large enough to hold all the apparatus with the switches either open or closed. It should be made from $\frac{7}{8}$ inch lumber and be not less than $3\frac{1}{2}$ inches deep, provided with a door which should be hinged from above so that the weight of the lid will always keep it closed. After having been well painted within and without with a good moisture repelling paint, it should be lined entirely on the inside with either sheet iron or sheet asbestos and the asbestos again painted. This will keep it dry and prevent any liability of fire from a blown fuse or from other causes. The holes through which the wires pass should be bushed with porcelain tubes, loom is sometimes used but is not suitable in damp places.

The usual form of main switch is known as a double pole, single throw, knife switch and of an ampere carrying capacity as required. Generally for a small house with a few lights this switch will be of 15 to 25 ampere capacity but a larger one is no detriment.

The fuse block or cut-out may be one with cartridge fuses or what is suitable for the low voltage circuits, with Edison screw plug fuses as in Fig. 18.

The wires from the battery should go to the fuse block or cut-out first and the house circuit wires to the switch. This allows the fuses to protect the entire circuit and the switch, if the switch should happen to be short circuited by accident, it having

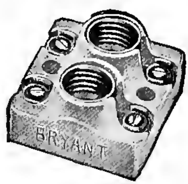

FIG. 18.

bare metal parts, the cut-out fuses would blow. But if the outside wires led first to the switch, a short circuit on the switch would not blow the fuses there but those at the battery if there were any. Note here and in all cases that a knife switch must be fastened *so that it opens downwards* and not upwards. This is so that it cannot drop shut after being left open.

In Fig. 19 is shown a diagram of a service switch and box where *C* is the cut-out with its fuses and *S* the switch. The wires from the source of electricity here come in at the top of the box and the house circuit wires leave from the bottom. This

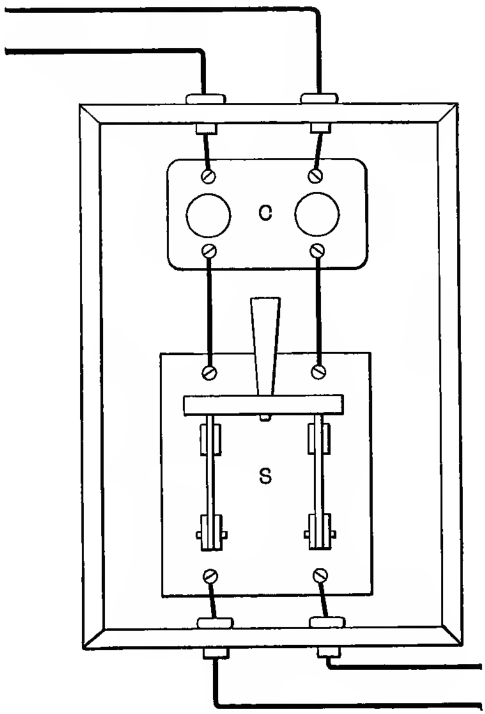

FIG. 19.

is the simplest arrangement of a cut-out and switch.

In Fig. 20 is another diagram where the house circuit wires and the service wires all lead out at the top. This is sometimes an advantage as the wires may be led away directly along the cellar ceiling beams.

A very convenient form of 25 ampere service switch for this class of work is that shown in Fig. 21.

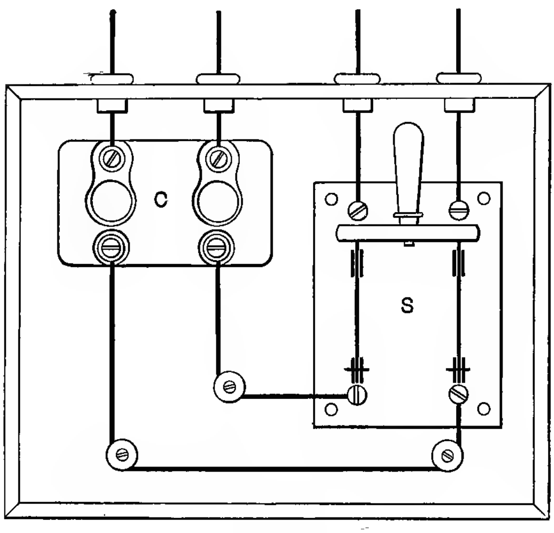

FIG. 20.

It is self-contained with both the switch and the cut-out and its fuses mounted on one base. This form of switch may be installed on an asbestos covered board, or even on a board painted with moisture repelling paint providing the location is not damp. But a cut-out box is easy to make, and is by far a safer and neater job, a lock and key

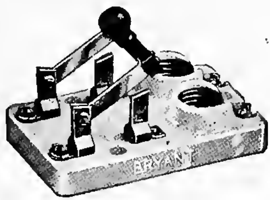

FIG. 21.

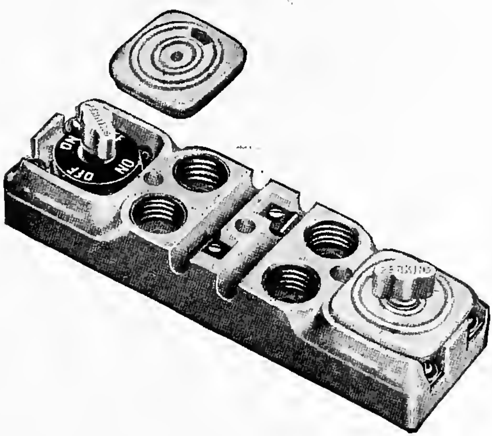

FIG. 22.

being added giving greater protection against any tampering with the main switch.

Where the house is a large one and it is best to divide the lights into several separate circuits each running to the cut-out box, the form of combined switch and cut-out shown in Fig. 22 is very suitable although for a cheaper job separate cut-outs and switches may be used. The arrange-

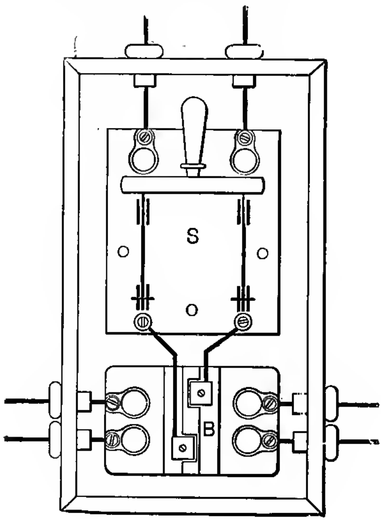

FIG. 23.

ment shown has snap switches but is also made with knife switches in a slightly different pattern. The one illustrated is neat enough to use where it is exposed should it be desired to put the switches controlling such separate circuits in a prominent place upstairs.

A service switch box made up with the self-contained switch before described is in Fig. 23. This box is arranged for two house circuits but more may be added as desired.

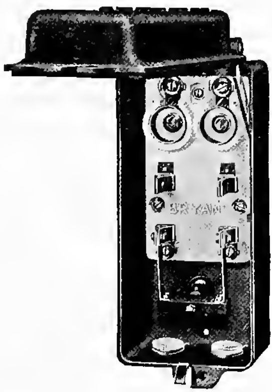

FIG. 24.

The form of service switch installed in an iron box shown in Fig. 24 is very convenient and ready for attachment to the wires. The switch is self-contained having plug fuses.

CHAPTER IV.

INSTALLING LIGHTS.

The Outlet Wires. The outlet wires may be tapped on now that the wires are in place and secured fast. Pieces of wire long enough to reach

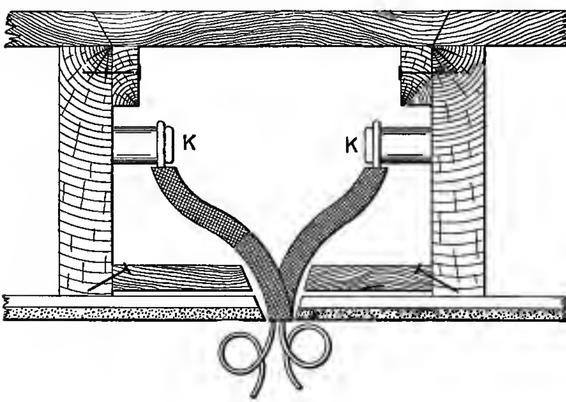

FIG. 25.

down through the outlet holes about eight inches and wrap around the knob and the main wire are cut off from the coil or odd short pieces are used. Before cutting them it will be well to fully under-stand how they are placed so that they may be cut to suit the location.

As in Fig. 25 the outlet wire is tied around the knob K, the short end bared and tapped on to the main wire and a piece of loom slipped on after which it is ready to be thrust down through the outlet hole. Tying it in this manner secures both the short piece and the main wire and takes the strain off the joint. *Leave the piece too long rather than short.* In cutting the outlet wire cut it long enough as it is easier to push up the slack from below or cut a piece off, than to splice a short wire.

Installing the Lights. Every joint having been soldered and taped and all wires in place the next operation is the last, that of connecting on the sockets or the fixtures. This is done after all wires are ready and the floor boards back in place, being generally a quick job.

Whether there will be regular fixtures or merely drop lights is a matter to be decided by the reader, but as the drop light is the cheaper and used very generally they will be next considered.

Drop Lights. In many places such as bathrooms, bedrooms and the kitchen, a drop light will suffice and save the cost of a fixture. Drop lights are made up in two ways, with fuses and without. The best plan is to make them up unfused and have the fuses in the cut-out box.

A drop light comprises three parts, the rosette, the cord and the socket, to which of course must be added the lamp. The rosette is the device by which the cord is attached to the main wires and also which supports the cord and lamp. It is of porcelain and has screws and lugs for attachment of the cord and the main wires, the fused rosettes being made in two readily separable parts.

The form of rosette shown in Fig. 26 is made to

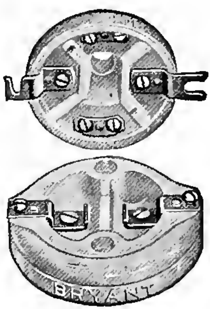

Fig. 26.

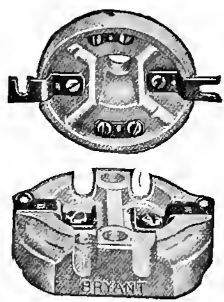

Fig. 27.

take a fuse and is used in concealed work where the wires come through the ceiling.

Another type for moulding work is shown in Fig. 27 and a cleat type used where the wires are run on cleats or otherwise exposed is shown in Fig. 28.

An unfused rosette is shown in Figs. 29. Making up rosettes is done the same way as with sockets in that a knot must be made in the cord to take the strain off the cord at the connecting clamps or screws.

Making up a Drop Light. The cord may be covered with cotton, silk or mohair as selected the twisted cotton covered being the kind most used. For low voltage lighting it is suitable but is not used in good work for regular 110 volt lighting. The sizes most used for single drop lights are No. 16

FIG. 28.

FIG. 29.

and No. 18 B. & S. The former will be better for low voltage work as its resistance per foot is less. For lengths of over 10 feet No. 14 should be employed.

The first operation is to measure the length of cord necessary so that the light will hang at the desired height. It should not be left too long as although there are plenty of cord adjusting devices for sale they all look unsightly.

Having cut the cord to the right length take a socket apart as in Fig. 30. Some sockets require that screws be loosened before the shell can be removed, others of more modern design are so made that a pressure on the shell near the point where it is slipped in the cap will loosen it so that it readily comes apart.

A hard rubber socket bushing is screwed into the hole in the cap to prevent the insulation of the cord becoming abraded.

Having separated the socket into its three parts

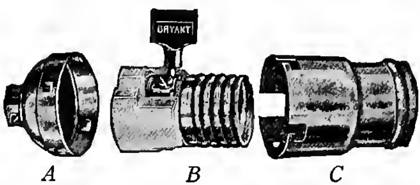

FIG. 30.

the cord may be untwisted for a few inches and the copper wires bared for about three-quarters of an inch on each part. The easiest way to do this is to lay the cord on the table and scrape off the cotton and rubber insulation. Then twist up the loose copper strands on both pieces so that they will not stray but lie neatly like a solid wire.

A knot is then made about an inch and a half from the end.

Loosen the screws on each side of the socket *B* and twist the wires under them once around. Twist in the same direction as the screw will turn when being tightened so that the turning of the screw will not push out the wires.

Tighten up the screws and twist any loose ends around the wire above the screw.

Then slip the cap *A* over the other end of the cord and the shell *C* on to the lower part of the socket. Press them together and it will be found that the knot will take the strain off the screws inside by catching against the inside collar of the cap.

Great care must be taken that no loose strands of wire are left inside the socket or a short circuit will result, loose strands must be looked for before closing up the socket.

Having made up the socket take the rosette apart and thread the cord through the hole in the cap. The cord must be inserted bearing in mind that the cap will be head downward from the ceiling. The top end of cord is then untwisted and its ends bared as before, knotted and made fast under the screws in the rosette cap.

All the drop lights for a job may be made up and put up at one time if preferred which is the usual way on large jobs.

When ready to put up the drop light the wires in the ceiling are threaded through the holes in the rosette base and the latter screwed fast to the ceiling. Where ceiling boards have been installed screws long enough should be used so that

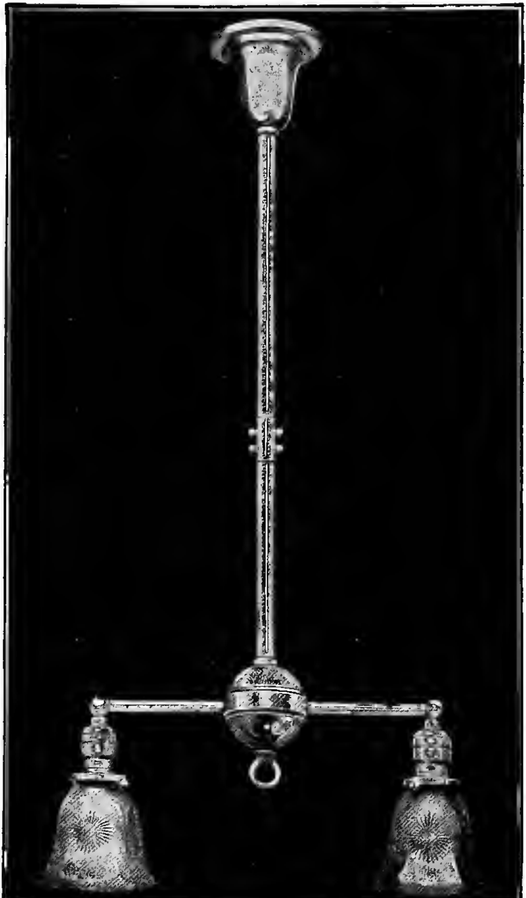

Fig. 31.

they penetrate it, a number 6 screw is heavy enough. The wires are then cut to length and scraped clean and fastened under the screw heads or lugs in the rosette base.

Fixtures. The choice of fixtures is a personal matter affecting both the purse and the taste, but it may be remarked that cheap fixtures are dear in the long run. All things have a market value and good articles bring their price.

Some tungsten lamps on account of their fragility require to be hung so that they are as free as possible from shocks. This requirement is met in the drop light but the ordinary class of fixtures are too rigid and transmit any shock from the ceiling to the lamp.

The class of fixtures known as the Mazdalier and illustrated in Figs. 31 and 32, are so made that they do not transmit shocks to the lamps and are therefore the cheapest for this class of work. They are made in a variety of styles, to suit all tastes but the limits of this book preclude any extensive cataloging of them.

There are also several devices called shock absorbers on the market for use with the older type of fixtures which being interposed in the stem or elsewhere guard the tungsten lamps from harm.

Switches. Switches are made in many styles and types to suit all conditions and will be treated of in their place. It is, however, most likely that

Fig. 32.

there will be one or more single pole switches installed to control some of the lights and the operation of installing them will be next treated of. The simple form of single pole snap switch is shown in Fig. 33 without its cover, and may be procured in many finishes to suit the fixtures, the most used finish for general purposes being nickel plate.

Switch Wires. The running of switch wires where simple single pole switches are used to

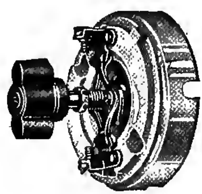

FIG. 33.

control a light from only one place as in Fig. 34 is as follows:

At the outlet in the ceiling or wherever the light is to be located, only one piece of wire *A* is brought down through the hole from the main circuit for the fixture.

Another piece of wire *B* is cut long enough to reach from the fixture up through the hole, fasten to the knob and run clear along the floor down to the switch outlet with enough left to make connection to the switch.

A third piece *C* is cut and run from the other side of the circuit at the outlet, that is from the main wire other than the one to which the outlet wire is connected. This second piece also runs clear down to the switch.

It will be seen then that the current passing down

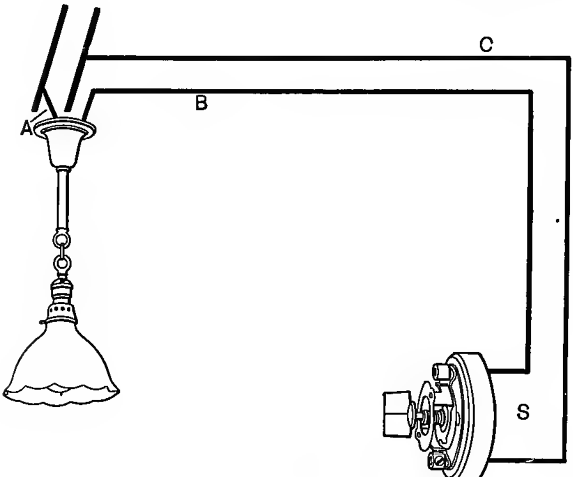

FIG. 34.

through the first short piece *A* through the fixture flows along the second length *B* through the switch and back to the circuit by the wire *C*.

Pulling down Switch Wires. To cut the loom for the switch outlets measure the distance from the switch outlet to the ceiling which should be the same for all switch outlets on the first floor. Then allow enough for the thickness of the ceiling or beam under the floor, and also be sure that the loom will reach in one piece from the outlet to the knob at the point where the switch wire leaves the joist to run down the wall. Then slip the switch wires into the loom and pull through the ends, bare the copper for a few inches and twist the ends together ready for attachment to the fish line.

The switch outlet having been cut in the wall through the lath and plaster the mouse is dropped down from above pulling the string along with it all but the loop end which is tied tightly to the twisted end of the switch wires.

A piece of hooked wire is then run in the outlet hole down-stairs and the fish line pulled through. Pulling on the line soon brings out the twisted ends of the switch wires, if they stick, they must be helped from above, it is very helpful here to have an assistant who can guide the wires down. The twisted ends are then loosed from the fish line and left for connection to the switch later on.

Hall Lights. It is often very convenient to locate a light in a hallway for instance so that by means of two switches it can be controlled from two places. A person desiring to go down-stairs at night can then light the lamp in the down-stairs hall before descending, by means of the switch up-stairs; and then after having descended can extinguish the lamp from the switch down-stairs. Or it may be lighted from down-stairs and extin-

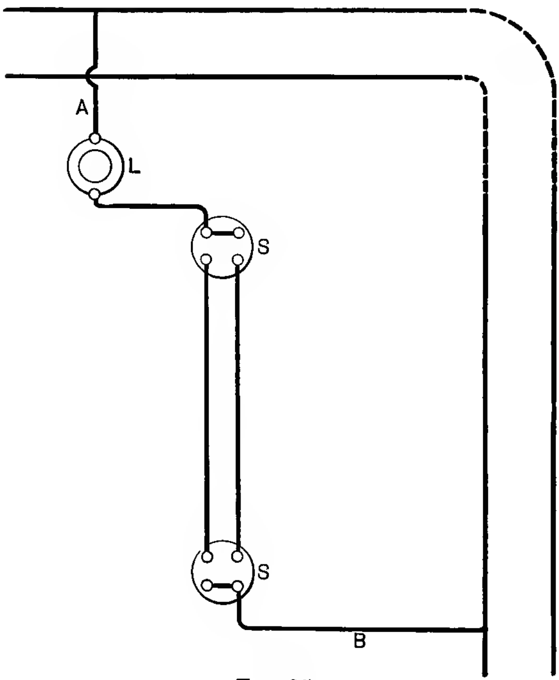

Fig. 35.

guished from up-stairs. Either switch will light or extinguish the lamp.

The wiring for this arrangement is not complicated but needs two special switches called "three way switches."

A diagram of the wiring is in Fig. 35. The rosette of the hall light *L* is connected on one side *A* to the circuit as shown and the other side of the rosette is connected to the single binding post on the switch *S* up-stairs. This binding post is quite easily distinguished as it is strapped to another which has no hole and screw for a wire. The same binding post on the switch down-stairs is connected *B* to the circuit but not to the same side of the circuit as the top switch rosette wire. Then two wires are run, one between each of the two remaining binding posts of the switches as shown.

Where there is an available circuit both up-stairs and down-stairs or the same circuits runs near each switch as shown, the wires may be attached to each taking care that they go to different sides of the circuit. But where there is no circuit down-stairs the lower switch wire must be run upstairs and tapped on to the same circuit as the rosette.

A study of the illustration will make this clearer than pages of explanation. It really is very simple.

What happens is as follows: When the button of one switch is turned it connects one live wire to *one* of the two switch-wires and the current flows along through the second switch and out through the lamp to the other live wire lighting the lamp. Now if the second switch is turned, it changes the lamp wire to the other switch-wire and the lamp goes out.

CHAPTER V.

Other Methods of Wiring.

Open Work or Cleat Work. Where appearance is no object the wires may be run on knobs or held by cleats on the ceiling or walls of the room. In the case of barns, outhouses and even in cellars this class of wiring may suffice. But it is not neat and even moulding work is better and more symmetrical.

The general directions for open work are not much different than for running wires between the floors except that cleats holding two wires may be used. The wire should be rubber covered and stretched tight between the knobs or cleats. Wires must be kept apart at all times and a generous use of knobs or cleats is recommended to that end.

Where a long run of open work is to be made, the two extreme ends of the circuit should be stretched tight first, that is of course on a straight run such as the whole length of a hallway or cellar. The end knobs or cleats being in place it is easier to put up the intermediate ones straight.

In general wires should be supported by cleats or knobs at least at every 4½ feet but often it is better to space them closer.

This class of work is a little hard for the beginner as the wires must be stretched tight in order to look neat. An assistant would be of use to help stretch the wire and hold it tight while it is being cleated and the screws driven home.

When the circuit turns at an angle the wires may be fastened as in Fig. 36 which shows the arrangement of the cleats although where the wire is stiff enough the middle cleat may be dispensed

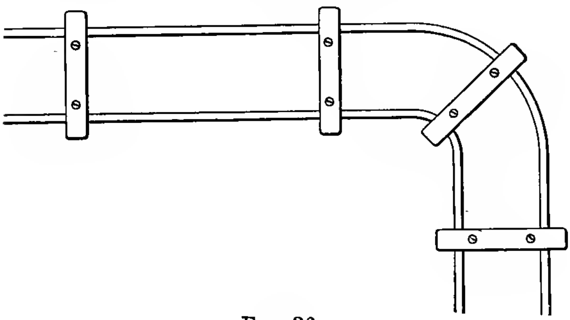

FIG. 36.

with. The cleats used are porcelain and come in pairs, some being interchangeable top and bottom.

This class of work should not be installed outdoors or where it is damp. The wiring of damp places is best done on knobs, and outdoors, except under cover, on glass insulators.

Where money is less an object than time or labor, loom may be used throughout dispensing with knobs almost entirely. Pockets are opened only at the outlets and at a few other places such as where the wires run down in the walls. The wire then being encased in loom for its entire length is pulled under the floors for the entire distance being left without loom at the outlets for a short space in order to make fast to the knob. Knobs are used at the outlets of course to secure the wires for the lights and the switches.

A snake wire of steel is useful to pull the loomed wires from outlet to outlet. This snake wire is of flat steel and one end being bent to prevent it catching in projections beneath the floor it is pushed under the floor boards and as it reaches an outlet the wires made fast at its other end are pulled along by its aid.

In some types of house construction there will be found a space between the joists and the plaster allowing the wires to be fished without boring the joists. Otherwise the joists must be bored and tubed as usual.

Wiring in Wooden Moulding. In buildings where it is not desired to wire on the plans described the wires are run in wooden moulding fastened to the ceilings or to the walls. This moulding consists of two parts, the backing which is a flat strip having grooves cut in it for the wires to lie in, and the capping, a thin lath which is nailed over the wires to hold them in place and to conceal them.

This moulding should be painted with a moisture repelling paint inside and out and the wire used must be rubber covered.

Under no circumstances should this moulding be used outdoors or in damp places.

In wiring with moulding, the backing is first nailed in place, the wire laid in the grooves and held temporarily in place by brads which are removed when the capping is nailed on. It is better to use screws instead of nails to fasten the capping as it may then be the easier removed when necessary. Whether nails or screws be used, they are to be driven through the central rib of the backing and not through the bottom of the grooves. It is best to plan so that there are no splices in the wires, but have them continuous throughout.

When taps are necessary they may be made as usual, by twisting the tap wires on and soldering them but a better plan is to use one of the tap devices described later on.

When the circuit turns at an angle, the moulding should be neatly cut and mitred as in a picture frame. This class of work is one where the mechanical skill of the operator becomes apparent as it is really joiners work and the neat fitting of the pieces in their place and the straightness with which the moulding is run are very noticeable. A great amount of ingenuity and taste may be displayed in the manner with which the work is done and a job of moulding may be either an eyesore or an ornament. Sometimes it is nice to continue the moulding beyond where the wires stop in order to gain symmetry of design.

Although it is often quicker to use moulding all the way, switch wires may be often pulled down inside the walls in loom and out at the switch outlet.

Moulding Taps. Where a tap is to be taken off a run of moulding one of the tap wires will

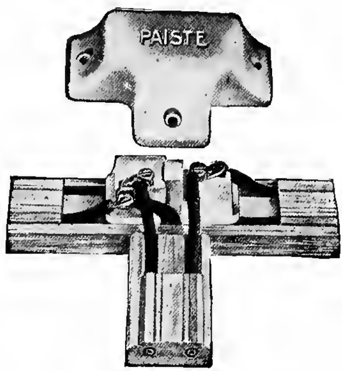

FIG. 37.

naturally cross the main wires and the moulding. The crossing tap wire is led out through a slot cut in the main wire moulding capping and crosses outside this capping which is thus interposed between the wires and keeps them apart. The other tap wire is led out of a slot cut in the outside wall of the main moulding and into the groove of the tap moulding.

A neater and better plan is to use the tap device shown in Fig. 37 which is made by the H. T. Paiste Co. of Philadelphia. It can be bought at almost any electrical supply store and is simple in attachment the illustration showing sufficiently well its application.

Where two circuits have to cross each other, a cross over device made by the same company is used as illustrated in Fig. 38.

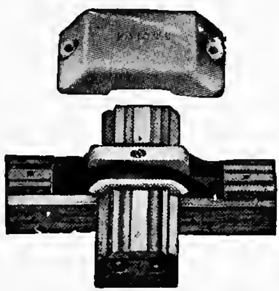

FIG. 38.

The moulding of the crossing wires is butted up to the main run of moulding, a piece of capping cut from the latter and the device installed as in the illustration. This interposes a solid base of porcelain between the two circuits.

Wall Moulding Method. One of the slowest and hardest jobs in wiring houses is the boring of innumerable holes through the floor joists to accommodate the circuit wires which run through them. In a house of six or eight rooms there may easily be a hundred of these holes and the boring of a hundred $\frac{11}{16}$ inch holes through floor joists with a brace and bit is no light task. Then the tubes must be inserted and the wires pulled through all of which may be saved if the operator is skillful and there is no objection to moulding on the side walls. This moulding may be of a special kind resembling picture moulding or it may be the regular electric wire wooden moulding as desired.

In this side wall moulding method the wires that otherwise would run through the holes in the joists up-stairs are run in moulding on the side walls down-stairs.

For example the main circuit that would run from the front of a house to the rear necessitating boring and tubing the whole distance may be run in moulding on the wall of the room below as shown by the heavy dotted line in Fig. 39. It may not run as straight as by the other plan but will only require a few feet more wire.

Taps for ceiling outlets *H*, *K*, *D*, *L* and *M* are taken off and fished up-stairs in loom then run as usual between the joists.

The number of pockets is also very much reduced and it is probable that there will be no need to take up an entire board anywhere.

The outlet at *G* can be run in moulding on the ceiling being fed by wires coming through tubed holes in the wall of the next room.

Where no picture moulding has been installed this special moulding or the regular kind is run

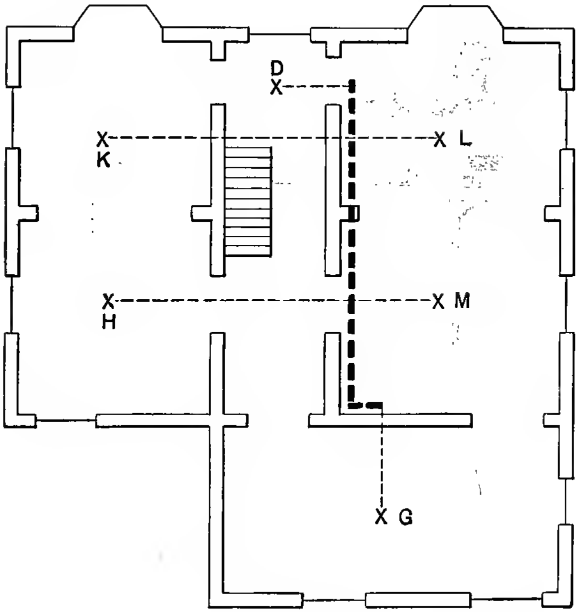

FIG. 39.

about 10 or 12 inches below the ceiling or to suit personal taste and the wall paper border.

As in the case of kitchen outlet *G* at partitions between two rooms the partition wall is bored and the wires pulled through in loom or tubes then continued on to the end of the circuit.

The ends for attachment to the cut-out box down-

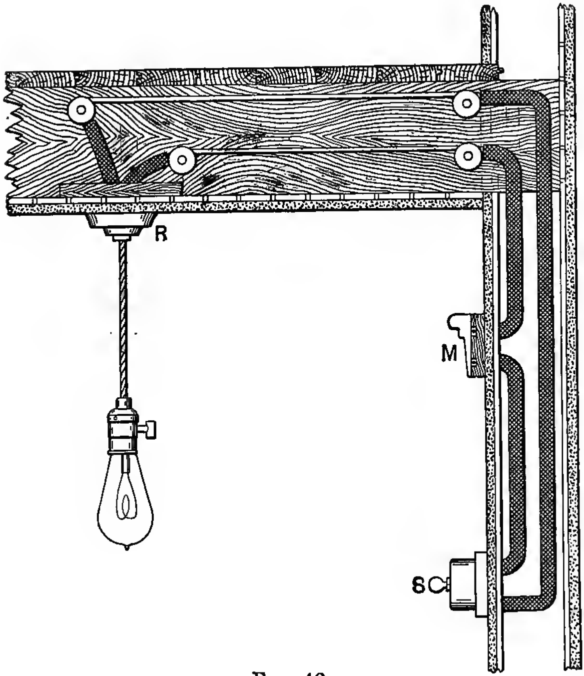

Fig. 40.

stairs or to the main switch are encased in loom and pulled up or down inside the walls, according as the service is up-stairs or down-stairs.

Taps running to ceiling outlets are to be run between the joists to a point as nearly above the moulding as possible then holes being bored through both moulding and wall the ends of these taps may be fished down and through them and soldered on to the wire in the moulding.

In the case of the live wire running from the main wires to a switch, this is easily pulled down to the outlet from a point in the moulding directly above it. Of course it should be loomed first. This makes a shorter run than in the ordinary method as the switch live wire may be taken from a near point right above it perhaps, whereas in the other method it has to run generally clear to the ceiling outlet. The wiring of a switch is clearly shown in Fig. 40 where *R* is the rosette, *M* the wall moulding and *S* the switch on the wall.

There is no practical difficulty about this system of wiring except that incurred by the appearance of the moulding or on account of the down-stairs wall running irregularly. It puts the wires where they may be tapped on for additional lights or wall brackets in a more accessible position.

Outdoor Service. When the battery is to be located in a separate building the wires leading to the house from the battery switchboard must be properly put up so as to withstand all weather conditions.

In the first case the wire must be weatherproof, triple braid the weights and sizes being given in Table 1. Sizes larger than No. 12 B. & S. should be stranded as thcy are then easier to handle and less liable to fracture when bent.

The insulators will be of glass and mounted on pins or brackets of wood or iron as may be decided.

Porcelain knobs should not be used to carry main wires where they will be exposed to rain or snow. In fact it is better to use glass insulators exclusively outdoors except of course where running a line for a light on the porch or in a similar case.

Before running an outdoor line, the route should be first surveyed. It should be run in as straight a direction to economize wire and must be supported at frequent intervals to allow for the weight of snow which accumulates on wires in the winter, and for the strain of heavy winds. In running long outdoor lines it is customary to allow at least a pole at each 125 feet but in the present case it will be better to keep well within this distance.

Although the wire itself may be exposed to the weather when properly supported on insulators, it is necessary to guard against rain running along it and entering the house by way of the entrance holes. This not only would damage the wall but would seriously endanger the insulation at the point of entrance. This contingency is guarded against by fastening the wires below the entrance

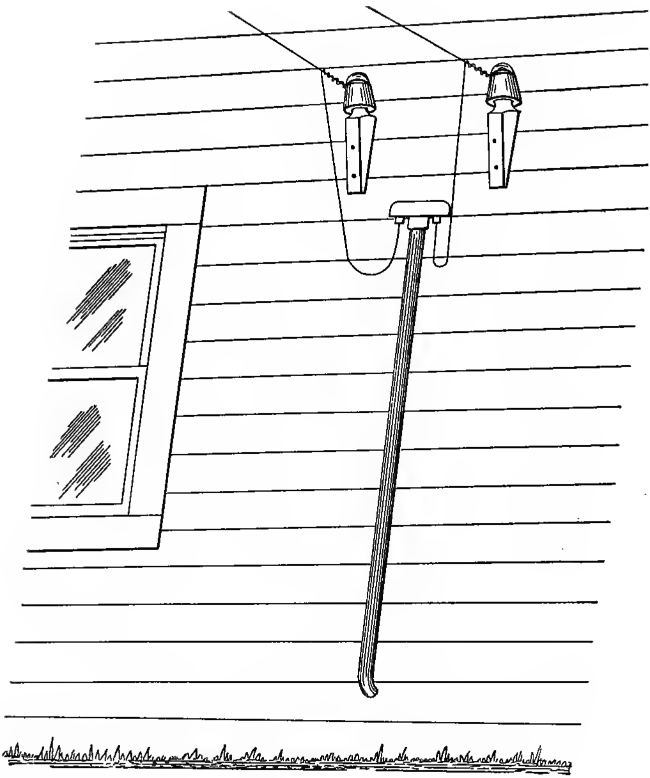

Fig. 41.

holes, giving them a loop from which the water can drip or by a combination of both.

The entrance holes must be bushed with porcelain tubes which are made for this purpose with a curve, which curve is to be turned downwards.

In regular 110 volt work, an iron pipe about 10 feet long is bent at its lower end so that it will enter the cellar, equipped with a proper bushing at the top and the wires pulled through. After this it is fastened up upright against the outside wall. Fig. 41. Two insulators on iron brackets are located at each side of the pipe at the top which should be at least 10 feet from the ground depending upon whether wagons are liable to pass near it and the angle with which the wires come down to enter it. The service wires leading from the battery or plant being then fastened to the insulators may be led in to the cut-out box or service switch.

It is generally easier to make up the pipe with two wires long enough to reach from the service switch up the pipe and leave enough free ends to connect to the wires coming from the plant.

Where suitable bushings are not used to close the end of the pipe outdoors, it should be filled with tape and a few wooden wedges driven in to keep out dampness. The wires, however, must be guarded against any possible cutting on the edges of the pipe. Bushings such as described are cheaper in the long run.

Where the wires come down from a pole set back

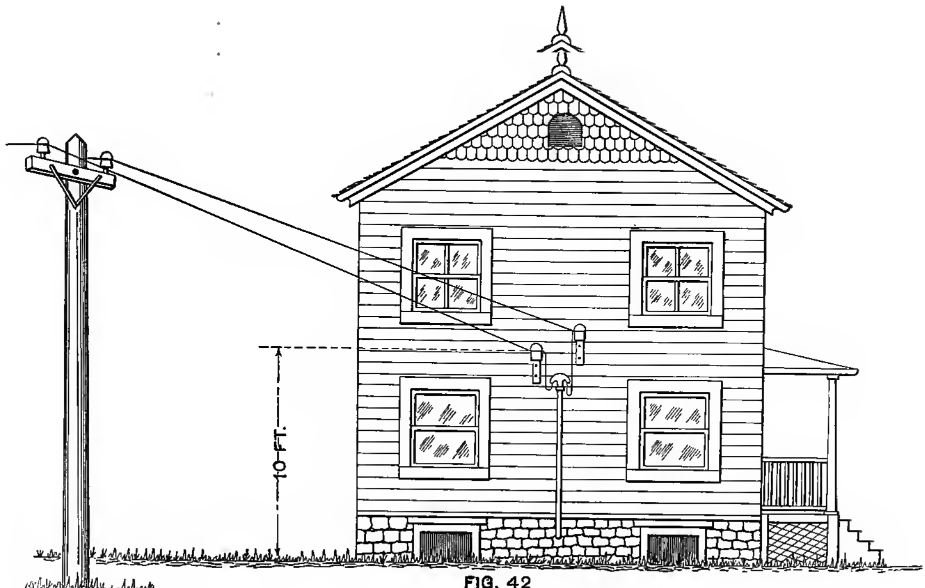

FIG. 42

of the house, one insulator will be mounted above the other so as to keep the wires apart as in Fig. 42.

Where the service wires come in up-stairs in the attic for example the pipe is dispensed with and insulators and tubes used. This method requires the use of a ladder unless the entrance can be located near a window.

CHAPTER VI.

NOTES ON MATERIALS.

Estimating the Material Required. To estimate the material required a careful survey must be made of the job after having digested the wiring directions already given.

The number of porcelain tubes will depend upon the number of joists and the wires running through them to which is to be added about 25% for use in odd places. Often from 150 to 200 will be required in a frame house of 7 or 8 rooms wired on the concealed knob and tube plan.

Knobs may be estimated at about 1 to each 3 feet of wire needed which allowance should be sufficient for most jobs.

The wire itself may be figured by measuring the route to be followed but a generous allowance should be made for ties or twisting around the knobs and also for the irregular manner in which it will run through the tubes in the joists. As wire is useful to have on hand allow 50% more than the estimate. This applies to small jobs, large jobs may be calculated to close figures and the wire bought in stock coils.

Flexible conduit or loom being somewhat expensive can be estimated somewhat closer if sufficient measurements are made. There will be two lengths for each single pole switch reaching from the switch to the space between the floor joists. This will average 12 feet per switch in rooms of ordinary height. For ceiling outlets short pieces a foot or less in length will suffice. From the circuit up-stairs to the cellar ceiling (or the attic floor) in the case of the service will be easy of measurement.

A roll of friction tape and one of rubber tape will be sufficient for quite a large job.

Other supplies such as nails or screws will be easy to figure.

Material Required in Wiring. No. 5 porcelain knobs for No. 12 or No. 14 wire have a groove $\frac{5}{16}$ inch wide to hold the wire, measure $1\frac{1}{4}$ inch from the top to the surface upon which the insulator is fastened and have a $\frac{1}{4}$ inch hole for the nail or screw. No. $5\frac{1}{2}$ porcelain knobs are similar except that they hold the wire higher from the surface wired over being $1\frac{9}{16}$ inches high.

Porcelain tubes should be unglazed and will vary in length according to circumstances. But in general for floor joists and most other woodwork in the house they may be 3 to 4 inches long measuring under the head. For places where two joists come together they should be probably 6 inches long. The inside diameter for wires not larger than No. 12 B. & S. should be $\frac{5}{16}$ inch and the outside diameter 9/16 inch. A tube 3/8 inch inside and 11/16 inch outside is preferable for No. 12 B. & S. wire, as it will be easier to pull through a lot of tubes when in the joists.

Split Knobs. Split knobs are porcelain insulators made in two pieces the wire being held tightly between the upper and lower portions when the screw through the center of the knob is tightened. Nails and nail heads should not be used with split knobs. For the latter reason it is very hard work to use split knobs under a floor and in similar places as there is not often enough room to handle a screw driver. Moreover there is a greater liability for one inexpert to insufficiently tighten the screw and the wire will be loose. And the breakage is liable to be greater.

In the solid knob method if the knob is not abolutely immovable on the joist it will at any rate hold the wire as the latter is not dependent upon the centre nail or screw. But with split knobs the screw has to perform the double function of holding the wire and holding the knob.

For wiring in exposed places where the screw driver can be used readily, split knobs are preferable as they make a neat job and the screw being the easier driven allows no excuse for loose wires.

Screws and Nails. Screws for switches and rosettes will be generally Flat Head Bright wood screws, No. 6 and from 1 inch to 2 inches in length, according to whether they are to be used in ceiling boards or only in lath and plaster.

Where screws are used for the knobs they should be also Flat Head Bright wood screws. For No. 5 and No. $5\frac{1}{2}$, $1\frac{3}{4}$ inch and 2 inch No. 8 are suitable although 2 and $2\frac{1}{4}$ give a firmer hold.

Wire nails are suitable for knobs, using nail heads as mentioned before.

Screws and not nails are needed where wooden moulding is run on plaster ceilings as nails will not hold.

Moulding. The wooden moulding ordinarily used in wiring is made of hard wood and painted with moisture repelling paint or varnish. The back as well as the grooves should be painted or varnished and the whole outside may be painted any desired color after being installed on the wall or ceiling.

The size for No. 12 to No. 14 wire is No. A-2 and has grooves $\frac{7}{32}$ inch wide. For Nos. 8 and 10 wire the size is No. B-1 with grooves $\frac{5}{16}$ inch wide. The size of the grooves should be specified in ordering special mouldings or the number of the wire given.

Bits. Bits used in boring holes for tubes or outlets will of course follow the size of the hole desired. If neat holes are desired use double cutter bits, if a lot of holes are needed such as under the floor and through the joists the work is much easier with single cutter bits such as the Ford bit.

Tubes really should fit tight but it is the general rule to use a bit a trifle larger than the tube and depend upon the fact that there is no motion to the wire to make the tube stay in place. For a loose fit use an 11/16 inch bit for tubes with an outside diameter of 9/16 inch and a 3/4 inch bit for tubes with an outside diameter of 11/16. The 11/16 inch bit will also be suitable for the outlets and the 1/4 inch loom.

In locating the first holes in the ceiling for marking outlets a 1/4 inch Syracuse bit is best, and may be as long as convenient one 18 inches long being most generally useful.

Tape. The real insulating tape is a rubber compound and must be put on with heat. It is best applied immediately after soldering a joint when it will adhere best but the joint may of course be heated later on and the tape applied. This rubber tape should not be confounded with the sticky or friction tapes. These are used merely to cover the rubber tape and protect it although often wrongly used for insulation.

The insulation at a joint should be at least as good as that on the wire itself.

Taped joints outdoors should be painted with P. & B. paint which is a rubber compound and not an asphaltum mixture. Failing genuine P. & B. a good grade of asphaltum paint is better than nothing.

TABLE 1.

COPPER WIRE PROPERTIES.

No. B. & S. gauge	Circular mils	Weatherproof Lbs. per thousand feet	insulation Carrying capacity amperes	Rubber insulation Carrying capacity
00	133,325	522	220	150
0	105,625	425	185	127
1	83,694	328	156	107
2	66,373	270	131	90
4	41,742	170	92	65
6	26,250	115	65	46
8	16,509	78	46	33
10	10,381	53	32	24
12	6,530	35	23	17
14	4,107	25	16	12
16	2,583	16	8	6
18	1,624	12	5	3

Figuring the Size of Wire. The size of wire used depends upon the amount of current to be carried and the distance it will travel.

Although a good conductor of electricity, copper presents some resistance. A wire that would carry 5 amperes without loss would not be suitable for 10 amperes if both currents were to travel the same distance. The results of resistance will be shown in a dimming of the lights. Moreover, if the wire be too small for the current carried it will get dangerously hot. Fuses will be used to take care of this excess current when it arises from a short circuit but for normal conditions the wire should be figured large enough.

The safe carrying capacity of copper wire is shown in the Table I. The lower limits for rubber covered wire is due to the fact that such wire is generally used enclosed where the heating would be more pronounced and also because rubber deteriorates more than the weatherproof wire insulation on being heated.

Although the carrying capacity will determine the safe size of the wire, it will not ensure its being large enough to carry the current without a loss. In low voltage lighting this loss must be considered, as for example a loss of 3 volts would be worse on a circuit of 30 volts and affect the lights more than would the same loss on a wire where the voltage was 110, being a greater proportion.

The resistance of a foot of copper wire one circular mil or one circular thousandth of an inch in area is about 11 ohms.

It is a fundamental rule of electricity that the voltage expended in carrying a given current a given distance depends upon the resistance in the circuit. It would actually need an expenditure of 11 volts to cause one ampere to pass through this circular mil foot of wire. Therefore supposing the voltage of the plant was 30, there would only be 19 volts left for the lamp.

Of course a wire so small would never be used, it would burn up with the current but it is used as an illustration.

In order therefore to have the wire of the right area it must have the proper number of circular mils which is determined by a simple calculation. Referring to Table I No. 12 B. & S. has an area of 6530 circular mils so it is clear that a foot of this would only expend 1/6530 of the 11 volts for the same one ampere for its area having been increased would have correspondingly reduced the resistance.

Applying these facts to a simple arithmetical formula gives a rule to calculate the size of wire for any current and any distance.

Take the entire length of the wire, both sides of the circuit *L*. Multiply this in feet by the amperes *A* to be carried and then multiply the result by 11, or the ohms in a mil foot of copper wire. The answer will give the size of wire in circular mils to carry the current the required distance, and a reference to Table I will show the numerical size of wire needed. This allows a loss of one volt. If more or less loss is allowed divide the above answer by the loss allowable.

For example, suppose 10 amperes is to be carried 200 feet and one volt loss allowed. Then the entire wire length will be 400 feet and 400 times 10 times 11 equals 44,000 circular mils. The nearest size of wire in the table is No. 4 B. & S. with 41,742.

Another example, 12 amperes a distance of 240 feet with a loss of 2 volts. In this case perhaps the voltage at the battery in a distant building is 32, and 30 is required at the lamps. Then the entire wire length will be 480 feet and the multiplying together of 12,480 and 11 equals 63,360. This divided by 2 equals 31,680. The nearest in the table is again No. 4 although a number 5 wire is made and would be perhaps nearer. But the extra area is an advantage in all cases.

As a formula the rule would be stated as follows.

$$\frac{L \times A \times 11}{\text{volts loss}} = \text{Area in circular mils.}$$

In the house itself where the distances are short and the number of amperes likely never to exceed 5 or 6, a number 12 B. & S. wire is suitable for 30 volt circuits and a No. 10 B. & S. for a 12 volt circuit.

CHAPTER VII.

NOTES ON UNDERWRITERS RULES.

The following notes are gathered from the installation rules of the National Board of Fire Underwriters. They are supplementary to the wiring directions already given.

In general all wires are to be considered as bare and live. No branch circuit is to carry lamps totaling a load of more than 660 watts on one cut-out. No wire smaller than No. 14 B. & S. is to be used except in fixtures or as flexible cord. All switches are to be wired so that the blades are dead when the switch is open, that is the line wires are not to be connected to the hinged or lower end.

Open Work in Dry Places. The wire should be either "rubber covered," with "slow burning weatherproof" or with "slow burning" insulation, the two latter, being trade names. Wires must be held on insulators ½ inch from the surface wired over and be kept 2½ inches apart. Knobs or cleats must be placed not over 4½ feet apart except in special cases for wires larger than No. 8 B. & S.

Open Work in Damp Places. Where exposed to moisture only, use rubber covered wire and where exposed to fumes or acid vapors use weatherproof insulation. Wires to be $2\frac{1}{2}$ inches apart and at least 1 inch from the surface wired over.

Moulding Work. Wires to have an approved rubber insulation and to be continuous without splices from fixture to fixture or outlet to outlet. When taps are necessary same are to be made with approved devices (such as the Paiste tap-let.)

Neither metal nor wood moulding is to be used in damp places, outdoors or concealed. Where run on the inside of outside brick walls or concrete walls must be run on a board which is first secured to the wall.

Concealed Knob and Tube Work. Wire to have approved rubber insulation and to be run on knobs, being kept 1 inch from surface wired over. Should be run on separate timbers and kept at least 5 inches apart. When passing through walls, holes must be bushed with continuous bushing. Or a piece of iron pipe may be used into each end of which a porcelain tube is slipped. These tubes must be long enough to prevent the wires from touching the iron pipes. Where wires run near metal pipes, the wires should be protected by porcelain tubes secured to the wires either by adhesive tape or by knobs. Wires should always run *over* pipes if there is room to prevent liability of moisture dropping from the pipe on the wire.

Service Wires. Service wires from the cut-out box to the outside end of the iron pipe should be of rubber covered wire. Weatherproof wire may be used for the remainder of the outdoor run. Cleats or porcelain knobs are not to be used outdoors where they may be exposed to wet weather but porcelain or glass petticoat insulators employed on suitable pins or brackets. Service wires fastened to buildings should be supported at least every 15 feet. When passing over roofs, wires are to be secured at least 1 foot over ridges or 7 feet over flat roofs.

Note. The term "approved" refers to articles which are inspected and approved by the Underwriters laboratory. Complete coils of wire bear an inspection stamp of approval after inspection.

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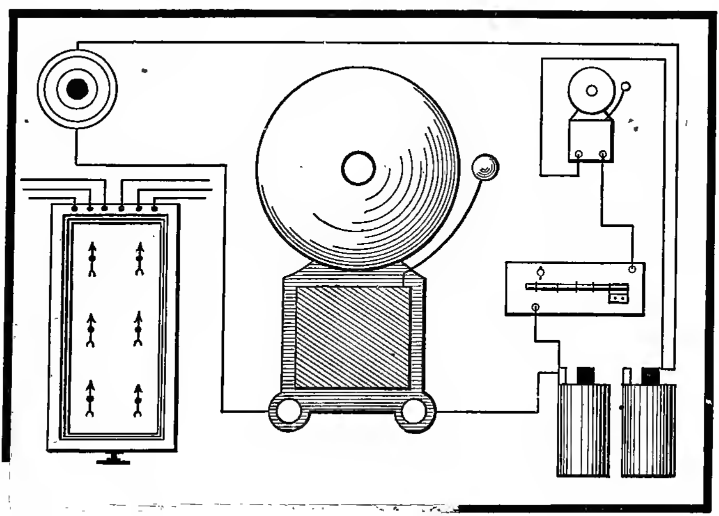

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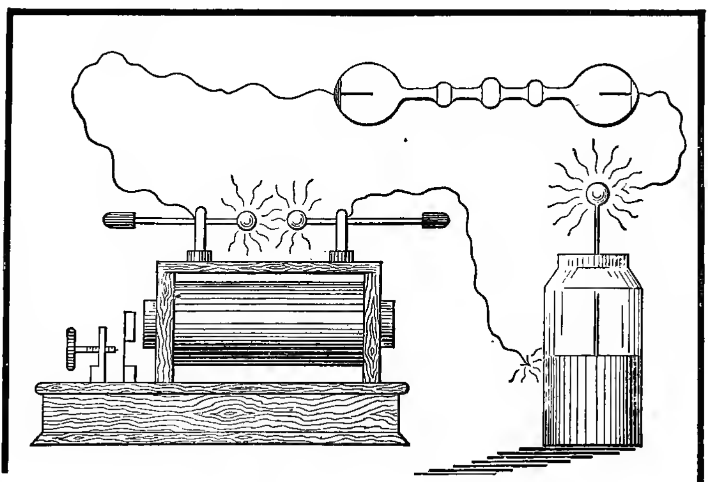

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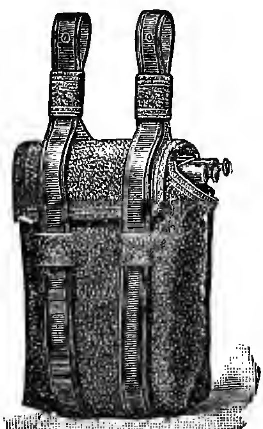

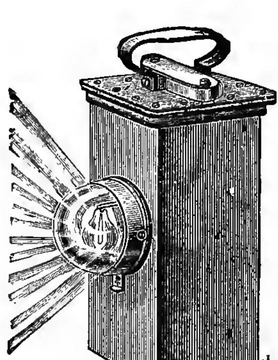

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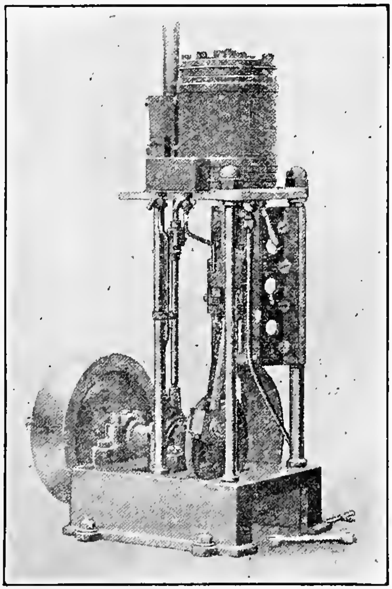

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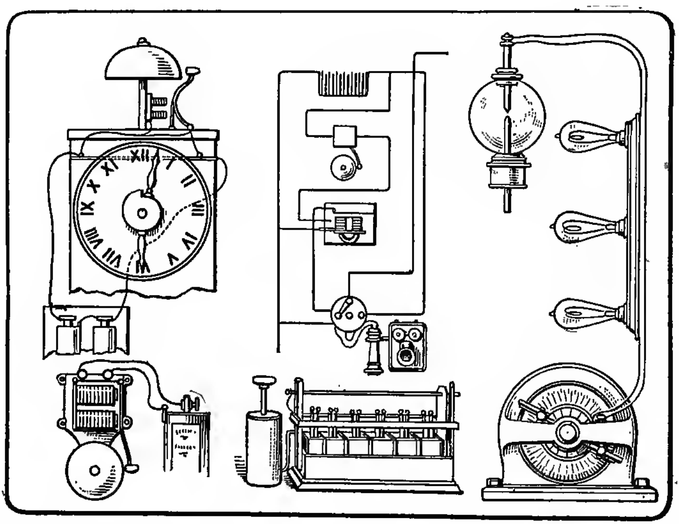

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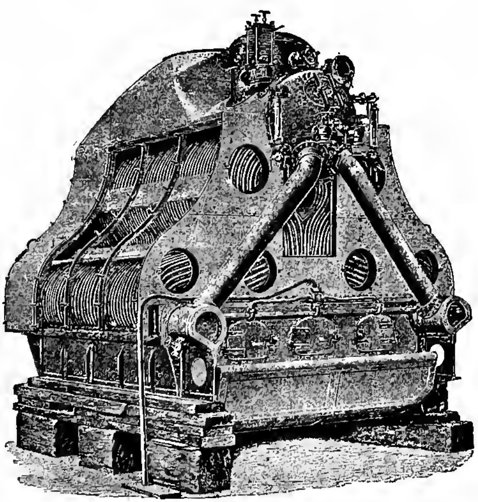

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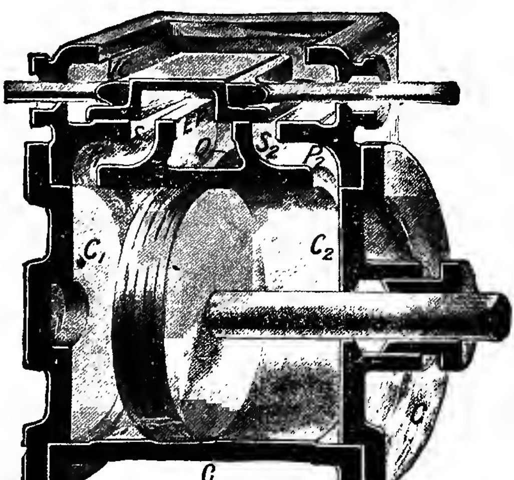

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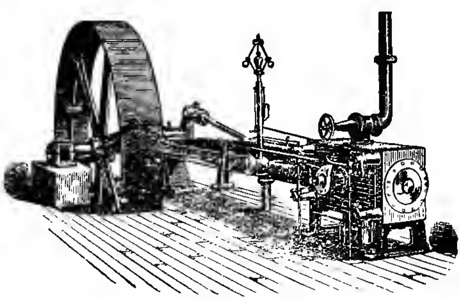

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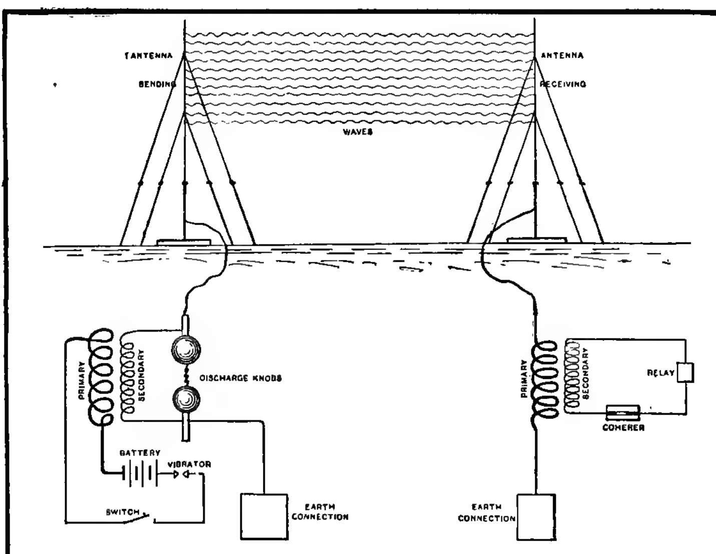

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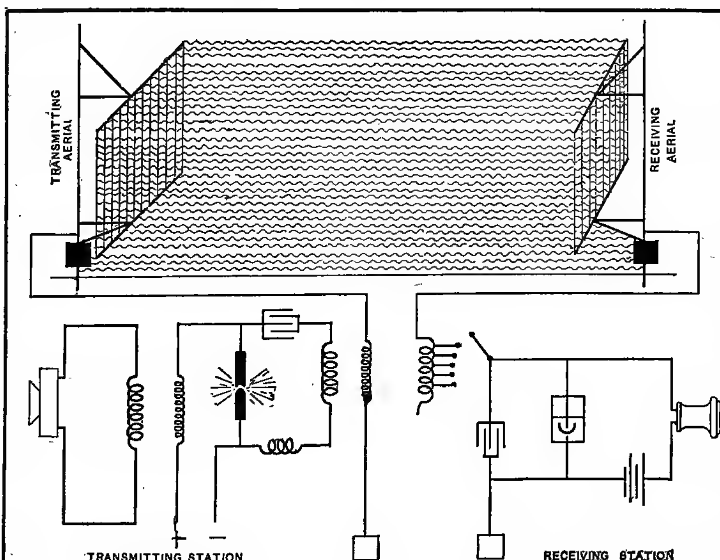

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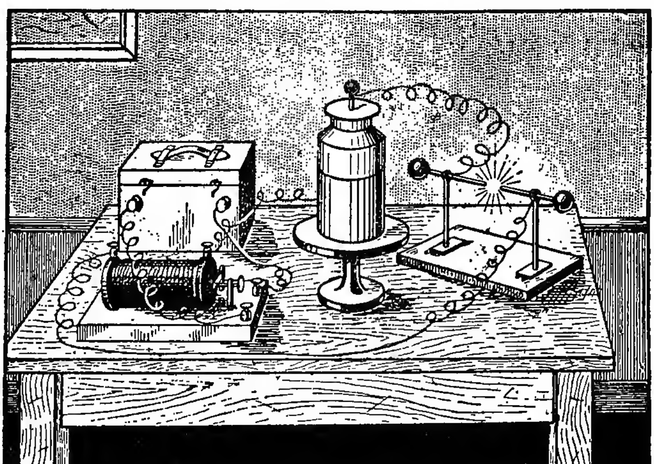

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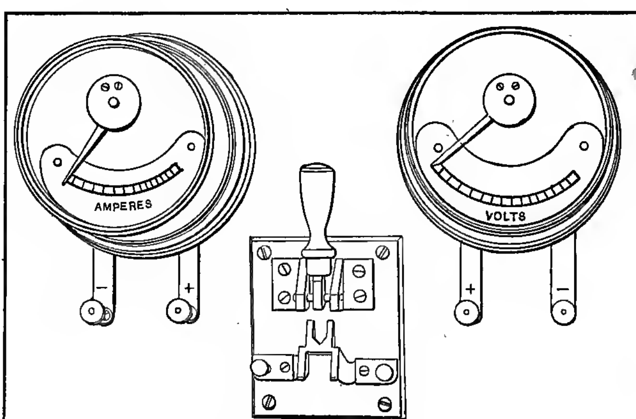

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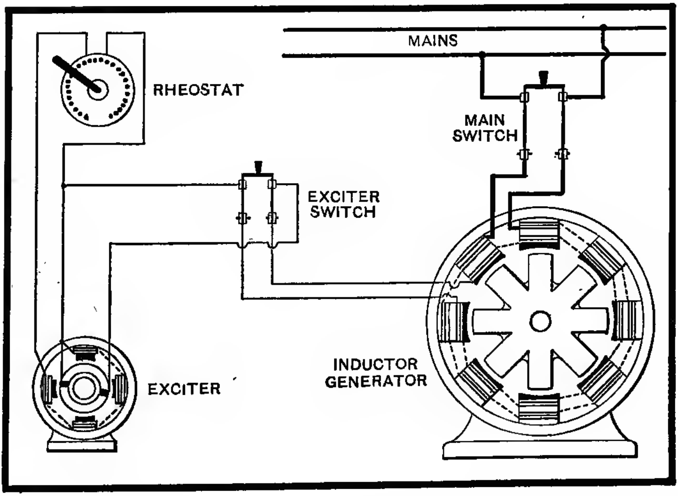

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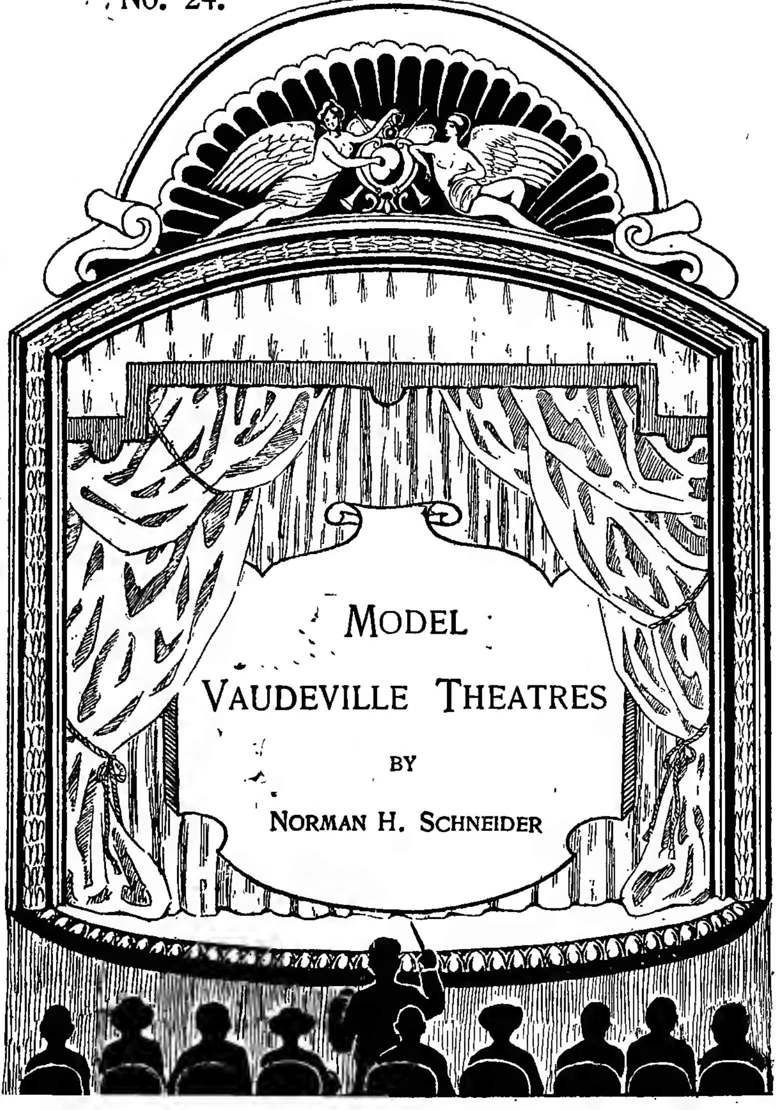

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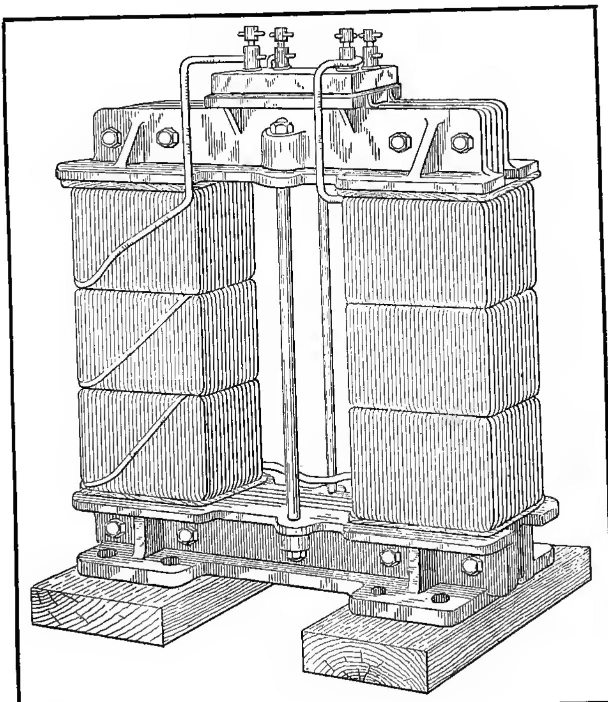

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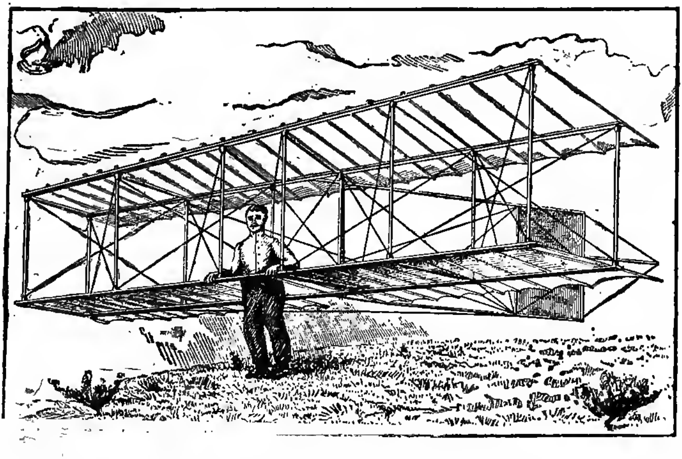

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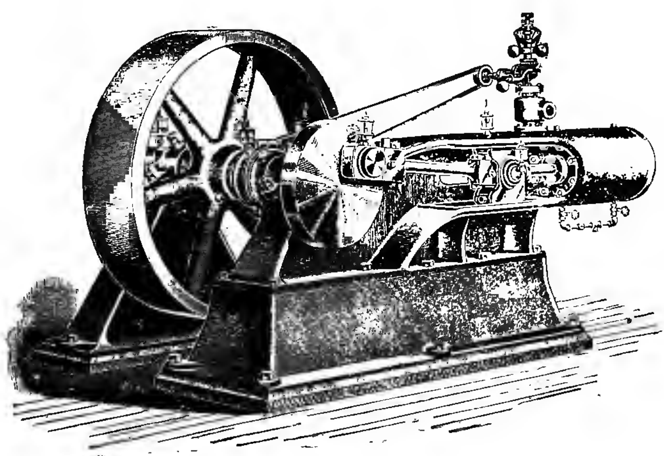

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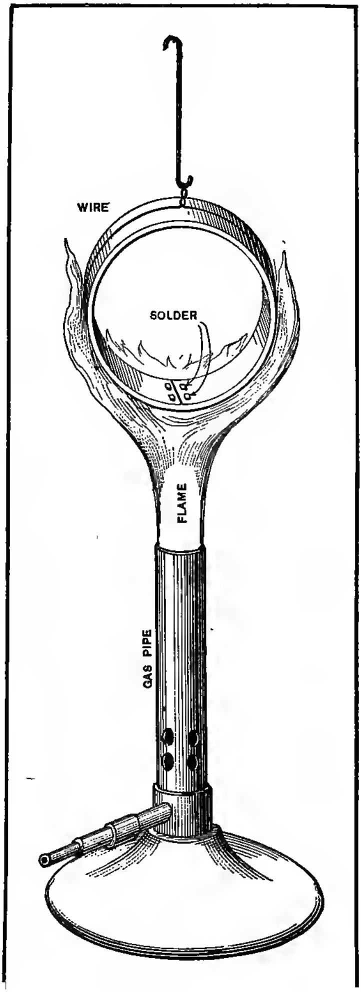

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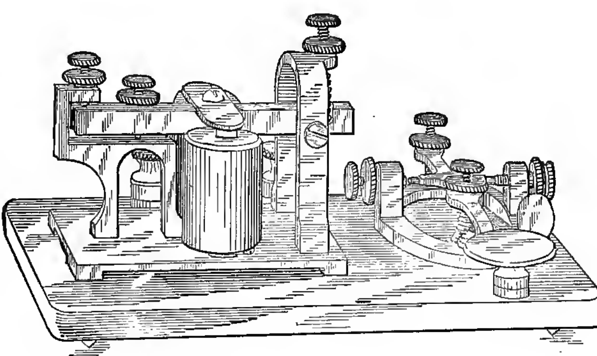

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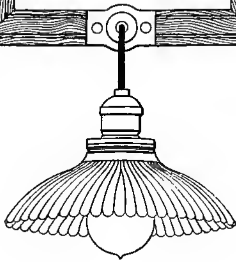

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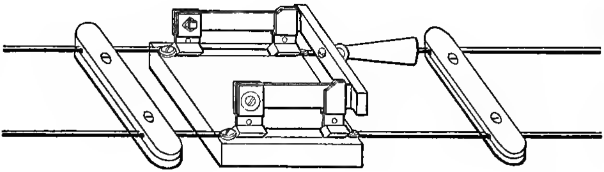

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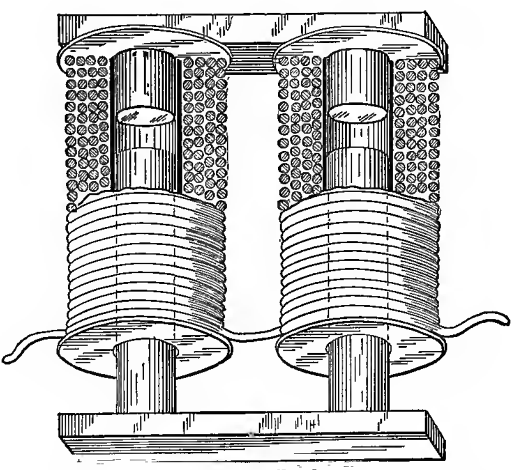

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